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# THE MILITARY UTILITY OF LANDMINES: IMPLICATIONS FOR ARMS CONTROL



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June 1994

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INSTITUTE FOR DEFENSE ANALYSES
Contract DASW01 94 C 0054
Task T-K6-1280

# PREFACE

This annotated briefing provides the results of a quick-response study performed by the Institute for Defense Analyses for the Office of the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict under task T-K6-1280, "Constraints on Antipersonnel Landmines in Future Conflict."

The study was motivated by the grave humanitarian problems posed by antipersonnel landmines in the developing world, and by the consequent growth of proposals to control their use, production, sale, or storage. In particular, the study is intended to assist the Office of the Secretary of Defense in formulating a position vis-a-vis upcoming Congressional legislation on landmine limitations, and the likely upcoming review conference on the Landmine Protocol of the UN Conventional Weapons Convention of 1981.

The annotated briefing evaluates the military utility of landmines in high intensity, mechanized land warfare and draws implications from this for landmine arms control. While military utility is clearly only one of a wide range of issues that must be addressed to determine whether any given arms control proposal is in the United States' interest, it is nevertheless an issue which has played an unusually important role in the debate to date, and is clearly an issue which must be addressed in order to reach a reasoned position. IDA is currently engaged in a broader assessment of the issues associated with landmine arms control; pending completion of that assessment, however, it is hoped that this more focused analysis will shed some important light on that broader debate.

The basic conclusion of the briefing is that issues of military utility in high intensity conflict need not preclude further consideration of any form of landmine arms control. A rather demanding set of assumptions and preconditions is required for the military utility of landmines in such conflicts to be so high as to make arms control unworthy of further consideration. And in particular, for the utility of *antipersonnel* mines to be so high as to preclude further consideration requires an especially demanding set of assumptions about the nature of future warfare. It is far from obvious that the required assumptions can be sustained.

Of course, this is not to say that any particular proposal is or is not in the U.S. national interest. Not only must a wider range of issues be considered to reach such a conclusion, but to do so ultimately requires a value judgment to weigh the dissimilar quantities associated with landmine arms control--and in particular, to balance the military costs of such limitations against their humanitarian benefits. Nevertheless, on the basis of the results obtained here, we believe that it would be a mistake to foreclose further consideration of those issues on grounds of military utility alone.

The authors appreciate the contributions of many individuals. In particular, Mr. Andrew Schneider provided valuable research assistance; and Mrs. Barbara Varvaglione provided timely and efficient production assistance. The briefing was reviewed by Col. W. M. Christenson (U.S. Army, ret.), Mr. Bernard C. Kempinski, Dr. Victor A. Utgoff, and Dr. Robert Zirkle of the IDA staff. In addition, Dr. Jeffrey Grotte, Mr. Christopher Jehn, and Lt.Col. Douglas Schultz (U.S. Army, ret.) of the IDA staff, and Gen. Ennis Whitehead (U.S. Army, ret.), an IDA consultant, provided helpful comments at various stages in the research.

# INTRODUCTION

## Background

Uncleared AP mines are a major humanitarian problem in developing world

- 85 - 90 million unexploded mines scattered over 62 countries
- 600 - 1200 people killed or wounded per month worldwide -- mostly civilians, often children
- 30,000 amputees in Cambodia -- ca. one per 236 Cambodians
- 15,000 amputees in Angola -- ca. one per 470 Angolans
- Large stretches of countryside uninhabitable
- Estimated clearance times measured in decades

Landmine export moratorium extension passed Senate by vote of 100-0 as amendment to FY1994 Defense Authorization bill (S. 1298)

Further Congressional action likely in conjunction with FY 1995 Authorization bill

Landmine Protocol to UN Conventional Weapons Convention of 1981 up for review in late 1994 - early 1995

Joint Staff, ACDA have prepared position papers on landmine arms control; OSD must formulate position

# SLIDE 1: BACKGROUND

At the request of the Humanitarian and Refugee Affairs branch of the Office of the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict (SOLIC/H&RA), the Institute for Defense Analyses (IDA) is conducting an analysis of arms control options for antipersonnel (AP) landmines. This document describes one part of that analysis: the military utility of landmines, and the implications of that utility for arms control.[1]

The analysis as a whole is motivated by the grave humanitarian problems posed by AP landmines, and by the consequent growth of proposals to control their use, production, sale, or storage. The State Department has estimated that some 85 to 90 million unexploded landmines are currently scattered over some 62 countries worldwide.[2] These mines kill or maim between 600 and 1,200 people a month -- most of them civilians, many of them children.[3]

Most of these injuries are the result of increasingly indiscriminate use of small antipersonnel mines by irregular or poorly disciplined armies in the developing world. In Cambodia, for example, the 12-year civil war between Khmer Rouge insurgents and government forces involved widespread use of landmines to deny opponents the use of key transportation routes and military positions --

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1 The larger assessment, of which this document represents only a part, is ongoing; it is anticipated that a review draft will be available to the sponsor by July 31, 1994.

2 *Hidden Killers: The Global Problem with Uncleared Landmines*, A Report on International Demining prepared by the United States Department of State Politico-Military Affairs Bureau, Office of International Security Operations, in implementation of section 1364 of the National Defense Authorization Act for FY 1993, p.3.

UN estimates run as high as 200 million unexploded mines worldwide: see Patrick Blagden, "Summary of United Nations Demining," in ICRC, *Report of the Symposium on Anti-personnel Mines: Montreux, 1993* (Geneva: International Committee of the Red Cross, 1993), p.117.

3 The State Department estimates that more than 150 people per week (or 600 per month) are killed or wounded by antipersonnel mines worldwide; the American Red Cross puts the figure at 800 deaths and 450 injuries per month. See, respectively, *Hidden Killers*, op. cit., p.2; Statement of Elizabeth Dole, president of the American Red Cross, on the use of antipersonnel mines, press release dated April 21, 1993, p.1.

Many small antipersonnel mines are surface-scattered, rather than buried, and some of the more common designs (such as the Russian-made PFM-1, or "butterfly" mine) have toy-like shapes, making them tempting objects for children to pick up: see The Arms Project of Human Rights Watch and Physicians for Human Rights, *Landmines: A Deadly Legacy* (New York: Human Rights Watch, 1993), pp.298-300. In a 1990 survey in Angola, the ICRC found that more than one-fourth of the sample group of 113 landmine victims were children: ibid., p.155.

but also to terrorize civilians or to deny the population access to key economic resources (especially arable agricultural land). As a result, an estimated 4 to 7 million unexploded mines are now distributed over a country about the size and population of the State of Georgia; of this population, some 30,000 Cambodians -- or about one out of every 230 people in the country -- are now amputees as a result of landmine detonations.[4] A substantial fraction of Cambodia's total national land area has been rendered uninhabitable, and the country as a whole now averages more than 50 unexploded mines per square mile of territory.[5]

The problem, of course, extends far beyond just Cambodia. In Angola, extended civil warfare has left an estimated 9 million unexploded mines and some 15,000 amputees (or about one per 470 people for the population as a whole). In Afghanistan, the war between the Soviet-supported government and the Mujaheddin rebels left behind 9 to 10 million unexploded mines; in Mozambique, a 15-year civil war left up to 2 million unexploded landmines and at least 8,000 amputees; in the Sudan, sub national warfare left some 500,000 to 2 million unexploded mines; in Ethiopia and Eritrea, some 300,000 to 1 million. The ongoing conflict in Bosnia has so far produced an estimated one to 1.7 million unexploded landmines, with perhaps 3.7 million remaining in the combined territories of Bosnia, Croatia, and Serbia. In many of the world's poorest countries, large stretches of economically vital land have been rendered uninhabitable, hospitals have been burdened with the care of the wounded, and political instabilities have been aggravated by the forced movement of rural villagers from mined agricultural land into already overcrowded cities.[6]

Nor is the problem likely to go away any time soon. Ongoing conflicts in the developing world are sowing more mines every day. And once sown, they are extremely difficult to clear. Demining is slow, expensive, and hazardous. Most humanitarian demining is done by hand, with one trained person typically able to clear only some 20 to 50 square meters per day.[7] To clear only the more dangerous sections of Cambodia has been estimated to require decades of concentrated effort, and it is likely that significant stretches of

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4 *Hidden Killers*, op. cit., p.64; *Landmines: A Deadly Legacy*, op. cit., p.166.

5 Given 4,000,000 unexploded mines in a country of about 70,000 square miles.

6 *Hidden Killers*, op. cit., p.64; *Landmines: A Deadly Legacy*, op. cit., pp.145, 149, 204-5.

7 Ibid., p.235. Note that humanitarian demining -- an area clearance operation with very high percentage clearance requirements -- is a very different undertaking from military breaching, which is typically performed in narrow breaching lanes for relatively short distances with much less demanding percentage clearance requirements.

mined countryside will never be cleared. More than 50 years later, for example, many World War II battlefields in Egypt and Libya remain off-limits to civilian traffic because of uncleared landmines.[8]

Given this, a growing list of proposals have been advanced to constrain the use of landmines in such conflicts. These proposals range from more or less traditional structural arms control (e.g., bans on the production, stockpiling, or use of particular mine types) to export controls, transparency measures, law of war restrictions, or international assistance for demining efforts.

Of particular importance for this analysis are a number of initiatives now before the U.S. government. The Congress, for example, has been actively engaged in efforts to limit the use of landmines in the developing world. As a result of Congressional action, the United States is now under an export moratorium on antipersonnel mines; a 3-year extension of this moratorium passed the Senate by the extraordinary vote of 100-0 as an amendment to the FY 1994 Defense Authorization bill (S. 1298). Further near-term Congressional action is likely in conjunction with the FY 1995 Authorization bill. In addition, the Landmine Protocol to the UN Conventional Weapons Convention of 1981 is likely to be brought up for review in late 1994 or early 1995 as a result of expected action by the French delegation. The United States, as a signatory to the Convention (though not yet a formal State Party -- the Convention has been submitted to the Senate for advice and consent to ratification, but no Senate action has been taken), will thus be required to respond.

In fact, the Joint Staff and the State Department's Arms Control and Disarmament Agency (ACDA) have already prepared position papers on landmine arms control.[9] As yet, the Office of the Secretary of Defense (OSD) has not; the purpose of this analysis is to assist OSD in doing so.

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8 Ibid.

9 *Antipersonnel Landmine Export Control Regime*, J-5A 00509-94, 4 February 1994, Confidential; ACDA, *Anti-Personnel Mine Regime*, draft, nd., Confidential. See also Headquarters, Department of the Army, *Information Paper: Landmine Arms Control*, 8 June 1994, Unclassified.

# Purpose

Assess military utility of landmines;  draw implications for arms control

- Many issues bear on desirability of landmine arms control, incl.:

    -- Verification
    -- Cost
    -- Humanitarian impact of regime
    -- Precedent
    -- Negotiability

- Military utility, however, has played especially important role in debate to date

- Assessment of military utility alone cannot determine whether arms control is in U.S. interest, but it can shed important light on debate

## SLIDE 2: PURPOSE

More specifically, the purpose of this document is to assess the military utility of landmines on the modern battlefield, to determine what implications this utility may have for landmine arms control, and to develop corresponding recommendations for OSD.

Of course, military utility is only one of a host of issues (most of them beyond the scope of this document), which bear on the advisability of any particular arms control proposal. With respect to landmines in particular, perhaps the most important of these is verification, monitoring and enforcement, given the small size of the objects to be controlled and the ineffectiveness of most, traditional, national technical means in this arena. While neither of these traits necessarily precludes satisfactory verification, by the same token it is at least a very challenging, and very important, issue.

Cost of compliance is another important issue. It entails expenses associated with required verification activities -- such as inspections or monitoring -- as well as those associated with disposing of mines in excess of permitted levels or with developing or acquiring new military capabilities required to compensate for those lost with the elimination of the affected landmines.

Also of importance is the humanitarian impact of an arms control regime. It has been argued, for example, that some proposed bans limited only to non-self-deactivating mines might not solve the underlying problem, as high failure rates for self-deactivation mechanisms could still render minefields uninhabitable pending hand demining. Thus, the ability of any given proposal to affect the underlying humanitarian problem must be assessed case by case.

Another factor bearing on the advisability of any particular arms control proposal is the precedent established by the proposed regime. For example, would a ban on AP landmines lead to restrictions on AP submunition weapons, which are similar in some respects to AP mines, or to limits on antitank (AT) as opposed to AP landmines, or to limits on unexploded ordnance in general?

Similarly, the negotiability of the proposed regime is an important consideration. It has been argued, for example, that developing states might not accept bans which exempt comparatively sophisticated systems like self-deactivating or switchable mines because they often regard such measures as attempts to restrict landmines to [illegible] countries able to afford the required sophistication,

But while many issues bear on the advisability of landmine arms control, the military utility issue in particular has played an especially important role in the arms control debate to date. And it is certainly impossible to reach a reasoned position on landmine arms control without reaching some conclusion as to the military effects of the proposed regime.

Moreover, the role of military utility in this debate is in some ways an unusual one for arms control. In traditional arms control, states are generally asked to reduce their own military capabilities in exchange for corresponding reductions in hostile military forces that directly threaten them. The purpose is reciprocal threat reduction, and in an important sense, what is being given up and what is being gained are directly comparable.

With landmine arms control, on the other hand, the United States is being asked to reduce or constrain a *military* capability to help address a *humanitarian* problem, and one that we neither created, nor benefit as directly from resolving as do many other states.[10] The humanitarian crisis created by antipersonnel landmines is not a result of their use by modern, disciplined, professionalized armies in the developed world. Such organizations are today capable of regulating their use of landmines to minimize the danger to civilians either during or after a conflict.[11] Rather, the humanitarian crisis has been created by indiscriminate mine use on the part of ill-disciplined, often sub national military forces in the developing world. To affect the latter in a meaningful way, it may well prove necessary to

10 Of course, this is not to argue that the United States does not have important national interests in the alleviation of human suffering abroad, or that the United States has not been willing to risk American lives in the furtherance of those interests -- or that we should not necessarily be willing to do so in the future. Rather, it is to argue that relative to more traditional forms of arms control, in which reductions of U.S. capability have been designed to induce corresponding reductions in hostile capabilities that themselves represent direct threats to the U.S., landmine arms control -- with its fundamentally humanitarian, rather than military focus -- is of a very different nature, and one that in important ways complicates the assessment of the advisability of any given proposal.

11 The U.S. Army, for example, follows exacting procedures for marking, recording, and reporting the locations of U.S.-laid minefields. In addition, authority to emplace U.S. minefields is held at the corps command level (i.e., a three-star general officer), and can be delegated no lower than the battalion command level (i.e., a lieutenant colonel). These procedures are designed primarily to reduce the danger of military fratricide, but, taken together, they also prevent indiscriminate or random minelaying, reduce the odds that civilians in the area would inadvertently enter a U.S. minefield, and facilitate postwar removal of such mines. For a more detailed description of U.S. procedures, see Headquarters, Department of the Army, *FM20-32: Mine/Countermine Operations* (Washington, D.C.: USGPO, 1992), pp.5-1 to 5-26, 7-1 to 7-19; also NATO STANAGs 2036, "Land Minefield Laying, Recording, Reporting and Marking Procedures;" 2990, "Principles and Procedures for the Employment in Land Warfare of Scatterable Mines with a Limited Laid Life;" and 2889, "Marking of Hazardous Areas and Routes Through Them."

restrict mine use by all armies alike (and in any case, such an argument is an important premise for any structural arms control regime for landmines). But if so, it nevertheless represents an unusually asymmetric form of arms control bargain, in which what is being lost and what is being gained are much harder to compare. Given this, it is especially important to develop the most accurate possible understanding of just what military capabilities are actually at stake in landmine arms control -- only then can the necessarily asymmetric comparison ultimately required here be conducted fairly.

Overall, then, an assessment of military utility is a necessary, but certainly not sufficient, condition for determining the advisability of any particular proposal for landmine arms control. While a more complete conclusion must thus await the completion of the broader, ongoing, IDA analysis, we feel that an initial assessment limited to issues of military utility alone can nevertheless shed important light on the larger debate.

# Outline

I. Military utility: the debate

II. Issues for analysis

III. Analytical approach

IV. Analytical findings

V. Conclusions and implications

VI. Limitations

## SLIDE 3: OUTLINE

The remainder of this document will proceed in six steps. First, it will briefly review the main issues, arguments, and assumptions in the debate to date over the military utility of landmines.

Second, it will distill from those arguments a series of "pressure points. [illegible] ...fferences in policy preference among the major players in the debate. These pressure points then become the issues for analysis later in the document.

Third, it will describe the approach for analyzing those issues.

Fourth, it will summarize the findings of those analyses.

Fifth, it will draw from those findings a series of conclusions and implications for landmine arms control (bearing in mind that military utility alone cannot in itself determine the advisability of any given arms control proposal).

Finally, it will outline some important limitations to be kept in mind when evaluating those conclusions.

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ARGUMENTS AND ASSUMPTIONS IN THE DEBATE OVER THE MILITARY UTILITY OF LANDMINES

## Military Utility of Landmines: The Debate

Arguments for U.S. retention of (unspecified) land mines:

- Landmines required for successful defense
  - -- provide economy of force
  - -- canalize attacks
  - -- increase attacker losses
  - -- reduce defender casualties
- Substitutes are inadequate
  - -- barriers require excessive labor; cause no attrition; are terrain-sensitive; destroy civil/economic infrastructure
  - -- artillery requires excessive volume of fire for equal effect; UXO creates worse humanitarian problem

Assumptions:

- US on defense only
- High-intensity mechanized land warfare
- Only land mine alternatives are barriers, artillery

## SLIDE 4: MILITARY UTILITY -- THE DEBATE

### Arguments

To date, the central military utility argument in the debate over landmine arms control has been that such weapons constitute an irreplaceable military capability. This is so, it is argued, for four reasons.

First, landmines provide economy of force. That is, they enable defensive positions to be held successfully by smaller forces, permitting commanders to use their available resources more efficiently.

Second, landmines canalize attacks. By reducing the amount of readily trafficable terrain, minefields can be used to force attackers to reduce frontages; to stack up their assault forces in successive echelons and commit them piecemeal at the point of attack; and to direct those echelons into prepared engagement areas where defensive weapons can be sited for maximum effect.

Third, landmines increase an attacker's losses. They do so in two ways. Mines inflict direct damage on attacking soldiers and vehicles which detonate the mines themselves. But they also cause damage indirectly by redirecting the attacker into disadvantageous locations, and by inducing attackers to slow down in the presence of enemy fire in order to remove mines from their path during the assault. By slowing down in this way, the attack force is exposed to defensive fire longer, and at greater standoff ranges (where defensive weapons are typically at greatest advantage relative to offensive return fire).

Fourth, landmines reduce a defender's losses. By increasing the attacker's losses, mines reduce the number of shooters available to return the defender's fire. And by delaying the attackers' closure with the defense, mines also reduce the effectiveness of that return fire. Lesser volumes of less-effective offensive fire mean fewer casualties for the defense.

Of course, if mines were unavailable, substitutes could be found. In particular, non-explosive barriers (such as ditches, craters, and abatis) are typically cited as potential substitutes, as is additional artillery fire.

Neither is generally held to be an adequate substitute. Barriers, for example, often require more labor and specialized equipment to create than is necessary to lay a minefield. They also do not directly kill soldiers or destroy vehicles, as do landmines; barriers affect the outcome only indirectly (by slowing or redirecting the attack and exposing the attacker to more effective defensive fire). Barrier effectiveness is also more terrain-sensitive than mine effectiveness: abatis, for example, can only be created in forests; craters require roads, defiles, or some other naturally canalized terrain to be meaningful; ditches are most effective where their use can be limited to blocking relatively narrow gaps in naturally impassable terrain, and where soil types are suitable. Moreover, some barrier types (such as bridge demolition or road cratering), may destroy important elements of the civilian infrastructure and thus in themselves, it is argued, create humanitarian problems.

Artillery, by contrast, is generally argued to require a prohibitively large volume of fire to produce effects equal to those of a typical minefield. Moreover, any individual artillery round has some probability that it will fail to detonate over the target. Especially when fired in the massive quantities necessary to compensate fully for the military effects of minefields, artillery thus poses a substantial risk that unexploded ordnance (UXO) will be left on the surface in the impact area following the battle. It has been argued that in the necessary quantities, the UXO problem that would result from such substitution would actually create a worse humanitarian problem than would a minefield of comparable military effectiveness.

**Assumptions**

These arguments are premised on at least three critical, but usually implicit, assumptions. First, they implicitly assume that U.S. forces are always the defenders. Granting that mines canalize attacks, increase attacker losses, or decrease defender losses, for these to be advantages one must be the defender -- if we were to assume that U.S. forces were the attackers, then all these properties of minefields become problems to be overcome, not virtues to be retained.

Yet at a minimum, other judgments could be made. Even in a theater-level defensive campaign, most defenders wage at least some tactically offensive warfare. And in fact, the U.S. Army has rarely been forced to fight a purely defensive theater-strategic campaign. In Operation Desert Storm, the United States waged a highly successful theater-level offensive. In Operation Just Cause, U.S. operations were primarily offensive. In Vietnam, much if not most U.S. combat activity was both tactically and strategically

offensive. In Korea, a defensive campaign ending in the establishment of the Pusan Perimeter was followed by an offensive one built around the Inchon landing and ending only in the Chinese counteroffensive on the Yalu River. In World War II, the U.S. Army was on the strategic offensive throughout its involvement in the European Theater of Operations. Of course, in any of these theater campaigns we have fought a mixture of tactically offensive and tactically defensive combat actions, but none has been exclusively defensive in nature. On the contrary, most of the Army's actual combat experience in the twentieth century has been in campaigns with primarily offensive theater level objectives. At a minimum, then, the implicit premise that landmines' net military utility is a function solely of their value to U.S. tactical defenders -- and not some amalgam of their advantages to U.S. defenders and their potential threat to U.S. attackers -- is thus an assumption that could reasonably be subject to question.[12]

A second implicit assumption is that in the future, the U.S. Army will be engaged essentially in high-intensity mechanized land warfare. The economy-of-force and canalization-of-attack effects cited as fundamental to landmine use are of unclear application in, for

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12 Of course, it could be argued that landmine arms control compliance may be limited to the United States and its allies (i.e., that our potential opponents will violate any agreement's provisions and retain their mines). And the greater the degree of non-compliance, the greater the degree to which the military utility issue comes to hinge on the value of mines to U.S. defenders alone (i.e., if the U.S. alone gave up landmines, the effect of this on U.S. tactical defenders would be the only aspect of warfare in which any change could be observed as a result of arms control, since U.S. attackers would continue, by definition, to face hostile mines in spite of any treaty).

But by the same token, if arms control *cannot* affect our potential opponents' landmine use at all, then no analysis of military utility is required to conclude that arms control would be not just a bad bargain but a pointless one: U.S. landmine use, as argued above, is not the problem. While limitations on U.S. mine warfare capabilities would be an inherent byproduct of any arms control agreement intended to limit other parties' behavior, limits on U.S. forces are not its direct purpose. If other states' use of landmines cannot be affected by arms control, then the military utility of landmines to the U.S. is immaterial -- such agreements would be incapable of fulfilling their intended function whether they constrain important U.S. military capabilities or not.

Pending a systematic analysis of enforcement opportunities, this question of compliance probability cannot be resolved.

But it should be noted that to justify *no* consideration of U.S. offense, one must assume that a putative treaty has no effect on hostile mine use whatever -- not that there is some cheating, or even substantial cheating, but rather that there is no compliance at all. If, for example, there is cheating, but to evade verification requires that cheaters reduce to some degree the size, effectiveness, or availability of their stocks, then the agreement would affect both U.S. defensive capability (presumably negatively) and U.S. offensive capability (presumably positively) to some, though certainly uneven, degree. To evaluate properly the advisability of such an agreement would thus again require an assessment of the military effects of mines both to defenders and attackers, and the two effects would have to be weighed against one another in some manner. Any non-zero compliance effect thus mandates some degree of attention to the military issues of U.S. offense against defensive mines; while expectations of non-compliance must be weighed carefully in interpreting the implications of that analysis, for the analysis itself to be unnecessary requires a rather extreme assumption with respect to compliance.

example, Operations-Other-Than-War (OOTW) such as peacekeeping, humanitarian aid provision in a hostile environment (such as in Operations Restore Comfort or Provide Hope), or non-combatant evacuation; or in low intensity warfare such as counterinsurgency.[13] Indeed, in many such operations, U.S. forces will be prohibited by the prevailing rules of engagement from employing landmines at all -- in Somalia, for example, U.S. forces used no mines (but did spend considerable effort, and lost some lives, dealing with hostile mines laid by indigenous forces).[14] Again, it is an assumption which could reasonably be subject to question that the only conflict type relevant for determining the net military utility of landmines is the kind of high-intensity warfare in which the landmine advantages cited above most pertain.

A third implicit assumption is that the only significant alternatives to landmines are non-explosive barriers and additional artillery. On the one hand, these are perhaps the alternatives whose immediate effects are most similar to those of landmines. But on the other hand, it is only an implicit premise that substitution is best pursued by duplicating the immediate effects of landmine use. From the standpoint of the larger national interest (or the individual soldier on the ground), what ultimately matters is the success of the operation as a whole, and the cost in lives and dollars incurred to secure this. To the extent that the removal of landmines reduces operational effectiveness, anything that increases effectiveness (or reduces losses) has some potential to provide offsetting effects that compensate fully for the removal of the mines. And the wider the set of potential substitutes considered, the greater the chances of finding one or more that are more efficient (i.e., that compensate fully at lower cost or fewer casualties) than those normally cited.

We could, for example, compensate for the elimination of landmines by increasing artillery effectiveness (rather than quantity) by substituting MLRS for M109 howitzers, or by substituting terminally guided antitank projectiles like SADARM for unguided submunition rounds like DPICM. Alternatively, we could retain more direct fire systems such as M1 tanks or M2 Bradley fighting vehicles. We could improve the speed of command decision making by accelerating the modernization of military data processing and communications equipment, or we could reduce the speed or accuracy of hostile decision making by acquiring more effective jamming

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13 Note also that the likelihood of compliance with any landmine arms control regime may vary significantly across varying types of conflict. In particular, the kinds of irregular, subnational military organizations most commonly encountered in low intensity conflict (and especially, in counterinsurgency) may be among those least likely to comply fully with any negotiated limits.

14 Telephone interview, Capt. David A. Dawson, Headquarters, United States Marine Corps, History and Museums Division, March 17, 1994.

and electronic deception systems. For any of these (or many other possibilities), the standard would be the ability to produce comparable end-state military operational success -- not merely the ability to provide economy of force, or canalization of attacks in the same manner as a minefield. It is thus, again, an assumption reasonably subject to question that the best way to substitute for a loss of landmines is to attempt to mimic their immediate effects via barriers and additional artillery.

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# ISSUES FOR ANALYSIS

# Issues

I. What kind of warfare will the army be conducting?

  How much defense (vice offense)?

  How much heavy mechanized land combat?

II. How large is impact of mines on defense effectiveness in heavy mechanized land combat?

  How does it vary across mine types?

  Are other potential substitutes available? How much is required?

III. What is net effect of land mines on US capability in other kinds of warfare?

  How does it vary across mine types?

Will focus here on II.

## SLIDE 5: ISSUES

This debate, and the assumptions that underlie it, imply three "pressure points," or fundamental questions that drive potential differences in policy preference. The first of these is: what kind of warfare will the U.S. armed services be conducting in the future? Or, more specifically, how much of the United States' future military activity will be tactically defensive in nature and how much will be tactically offensive; and how much of this will take the form of high intensity mechanized land warfare, as opposed to low intensity conflict and operations other than war? These questions in turn imply a second and third set.

The second set pertains to those conflicts involving heavy mechanized land combat, and in particular: how large is the impact of landmines on defense effectiveness in such fighting? It is one thing to say that mines, on balance, are likely to favor defenders under such conditions, but is the effect large or small?

And perhaps more important, does the effect vary across mine types? The military utility debate has not to date been systematic with respect to the effect of mine type on military outcomes -- "landmines" are usually addressed as an undifferentiated whole. Yet there may be reason to believe that antipersonnel and antitank mines, for example, could have very different utilities on the future battlefield. Certainly most arms control proposals distinguish explicitly between antipersonnel (which are generally the subject of limitation) and antitank mines (which are generally not). Given this, it is important to understand what, if any, differences exist in the magnitude of the military effects induced by these two classes of mine.

Alternatively, are other potential mine substitutes in fact available, and if so, how efficient are they? That is, how extensive must the substitution be to compensate fully for whatever loss of military effectiveness may be involved in any particular arms control proposal? Does the efficiency of substitution vary across differing potential substitutes, and if so, which is the most efficient choice?

The third set of questions pertains to conflicts other than high intensity mechanized warfare, and in particular: what is the net effect of landmine use on U.S. capability in such conflicts? Does landmine warfare benefit low-technology indigenous opposition forces

(who often see it as an inexpensive equalizer by which to neutralize U.S. advantages in firepower and mobility), or does it work to the advantage of the more sophisticated combatant? And once again, does the balance of advantage vary across varying mine types?

The answers to these questions bear heavily on the degree to which military utility bars or permits arms control for landmines. If, for example, the United States can expect to be fighting mostly defensive actions in the context of high intensity mechanized conflicts, then it is likely that the defensive advantages of landmines would make them a net advantage to the U.S. If the magnitude of the advantage is large, if it pertains more or less equally to all mine types, and if it is difficult to compensate with other kinds of combat power, then the military need for such capability would likely outweigh other considerations and largely preclude arms control -- as has often been argued.

But if the magnitude of the effect were modest rather than large, or if it pertained mostly to antitank rather than antipersonnel mines, or if it were easily counterbalanced by force improvements of other kinds, then it would at least become possible for some forms of potential arms control agreements to be in the U.S. national interest (although, again, whether any particular proposal is ultimately advisable depends on many issues beyond military utility per se, and in particular, on questions of verification and enforcement). Alternatively, the greater the future significance of low intensity conflicts or operations other than war, and the greater the degree to which the balance of mine warfare advantage in such conflicts lies with our opponents, then the greater the potential opportunity for advantageous arms control agreements.

While all three classes of question are thus important, this document will concentrate the analyses below primarily on the second -- that is, assessing the magnitude of the impact of mine warfare on high intensity mechanized conflict, evaluating potential variations across mine types, and considering the effects of potential mine warfare substitutes.[15]

15 For a more detailed treatment of the first and third questions described here, the reader is referred to the (forthcoming) documentation of the more extensive IDA analysis now ongoing.

# ANALYTIC APPROACH

# Analytic Approach

Test effect of key assumptions using Janus experiments -- fight simulated battles with/without AP/AT mines

- Consider mix of US defense *and* offense
- Consider effects of US *and* hostile mine use
- Consider wider range of potential substitutes for landmines

## SLIDE 6: ANALYTIC APPROACH

To address this second class of questions, we rely primarily on a series of simulated battles fought using the Janus combat simulation model.[16] Janus is a two-sided, stochastic, interactive, highly disaggregate division/brigade level computer model originally developed by the Lawrence Livermore National Laboratory and in wide use by the U.S. Army, Marine Corps, and National Guard (as well as several other NATO member nations), both as an analytical tool, and for training field grade officers.[17] It has attained an unusually wide acceptance within the military and defense analytical communities, and has been subject to considerable empirical validation effort -- especially through systematic comparison of simulation output and the results of U.S. Army field exercises on the instrumented test range of the Army's National Training Center at Fort Irwin, California.[18]

The purpose of these simulations is to produce a series of controlled experiments in which antipersonnel mines, antitank mines, and various possible mine substitutes are added to or subtracted from the battle and the effects of those variations on simulated outcomes are observed in order to investigate the questions posed in the previous slide. In particular, the experiments consider a mix of U.S. tactical offense as well as tactical defense; they consider both U.S. and hostile mine use (especially where the U.S. is on the attack); and they consider a wider range of potential substitutes for landmines than simply non-explosive barriers and additional artillery.

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16 While computer simulation modeling is certainly not the only means available for investigating the questions posed above, it is, we feel, a particularly powerful way of exploring questions relating to relative magnitudes of effects, and for issues where the existence of certain effects is unclear or in dispute (e.g., the ability of mines to affect the outcome of a U.S. attack as well as a U.S. defense). While the larger IDA assessment, of which this document is a part, will pursue a variety of assessment methodologies, the current document will thus focus on the findings of the Janus analyses in particular -- and on the derivation of arms control implications from those analyses.

17 More specifically, the analyses were conducted using Janus-Army version 3.17, Open Systems. For a more detailed description of Janus, see Department of the Army, *User's Manual, Janus 3.X/UNIX*, Headquarters, TRADOC Analysis Center, ATRC-ZD, Ft. Leavenworth, KS 66027

18 See, e.g., L. Ingber, H. Fujio, and M.S. Wehner, "Mathematical Comparison of Combat Computer Models to Exercise Data," forthcoming in *Mathematical and Computer Modeling*; L. Ingber and D.D. Sworder, "Statistical Mechanics of Combat with Human Factors," forthcoming in *Mathematical and Computer Modeling*; and L. Ingber, "Mathematical Comparison of Janus(T)," in S.E. Johnson and A.H. Lewis, eds., *The Science of Command and Control: Part II -- Coping with Complexity* (Washington, D.C.: AFCEA International Press, 1989), pp.165-176.

## Experimental Design

Base case i: U.S. mechanized brigade in defense, desert terrain (U.S. Army NTC, Ft. Irwin, CA)

- Mech battalion TF in strongpoint defense with tank battalion counterattack
- OPFOR division attack with two motorized rifle regiments in main effort
- Block and turning minefields used to canalize attack into prepared engagement area
- Disruption minefield used to break up assault formations
- Fixing minefield used to hold attacker at optimum engagement range
- Protective minefield used for close-in defense
- OPFOR employs scatterable AT mines to defend flanks

Excursions

a. No mines, no substitutes, U.S. or OPFOR

b. No AP mines, no substitutes, U.S. or OPFOR

c. No mines, U.S. or OPFOR, additional U.S. artillery as substitute

d. No mines, U.S. or OPFOR, improved U.S. artillery (MLRS) as substitute

e. No mines, U.S. or OPFOR, additional U.S. direct fire systems as substitute

f. No U.S. counterattack

## SLIDE 7: EXPERIMENTAL DESIGN

The design of these experiments takes the form of two control, or base case, scenarios, and a series of excursions from each in which key properties are varied. For each scenario (base or excursion), 15 repetitions of each battle were fought; the results are reported in terms of mean combat outcomes for those 15 repetitions (typically in terms of U.S. vehicle losses; the associated loss-exchange ratios and fractional loss-exchange ratios are provided in notes to the text), with 95 percent confidence intervals for those means provided as a measure of the spread in the individual results. Analytical findings thus consist of comparisons of base case and excursion outcomes, with appropriate statistical tests provided to measure the significance of the observed differences.

The first of these two base cases involves a U.S. mechanized brigade defending on a roughly 15-km frontage in desert terrain.[19] In particular, the terrain used was taken from the Army's National Training Center in the Mohave desert at Fort Irwin, California.

This mechanized brigade consists of one mechanized infantry battalion TF (task force), one tank battalion TF, and roughly one artillery battalion equivalent in direct support (an additional infantry battalion TF attached to the same brigade is assumed in action outside the simulation area and was not modeled).

The infantry battalion TF consists of three infantry companies (equipped with M2A2 Bradley Infantry Fighting Vehicles), one tank company (with M1A1 Abrams tanks), one antitank company (with M901 Improved TOW Vehicles), and one 4.2 inch mortar battery.

The tank battalion TF consists of three tank companies (with M1A1s), one infantry company (with M2A2 Bradleys), and one 4.2 inch mortar battery.

The direct support artillery complement consists of three batteries of M109 self-propelled 155mm howitzers, and one battery of MLRS (Multiple Launch Rocket System).

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19 This scenario is drawn from the brigade defense example given in Headquarters, Department of the Army, *FM71-3: Armored and Mechanized Infantry Brigade* (Washington, D.C.: USGPO, 1988), p.4-15.

These forces are disposed with the mechanized battalion TF in a prepared strongpoint defense and the tank battalion TF in reserve, poised to execute a counterattack into the flank of an attacker assaulting the infantry battalion strongpoint.

They are opposed by a Soviet-style OPFOR (OPposition FORce) division in the attack, with two motorized rifle regiments in the main effort, one motorized rifle regiment in a supporting attack (outside the simulation area and not modeled), and one tank regiment in reserve, available for exploitation in the event of success.[20]

Each motorized rifle regiment consists of three motorized rifle battalions (each with three companies equipped with BMP2 infantry fighting vehicles, and one battery of 120mm mortars), and one tank battalion (of three companies equipped with T72 tanks), with one 122mm self propelled howitzer battalion forward to support the attack by direct fire.

The tank regiment consists of three tank battalions (each with three tank companies equipped with T72 tanks) and one motorized rifle battalion (with three companies equipped with BMP2 infantry fighting vehicles, and one battery of 120mm mortars), with one 122mm self propelled howitzer battalion available to support the exploitation by direct fire.

In addition to the artillery positioned forward with the regiments, the division main effort is supported by a further four battalions of 152mm self propelled howitzers, two battalions of 122mm self propelled howitzers, one battalion of 122mm multiple rocket launchers, and one battalion of 220mm multiple rocket launchers.

The U.S. defenders are supported by a very extensive landmine deployment. This consists of an integrated combination of *block, turning, disruption, fixing*, and *protective* minefields. Each type of minefield serves a different purpose, and contains a different mix and density of mines.[21]

"Block" minefields are intended to halt attacker movement (in conjunction with accompanying fires) and deny outright the use of key terrain. They are located in positions where they cannot readily be bypassed, and contain a mixture of antitank and antipersonnel

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20 It is assumed that unengaged echelons will be committed only in the event of success by engaged echelons (defined as an advance reaching its objective with losses of under 60 percent of forces engaged).

21 For a more detailed discussion, see Headquarters, Department of the Army, *FM20-32: Mine/Countermine Operations*, op. cit., pp.2-2, 2-5 to 2-12.

mines with antihandling devices to complicate clearance. Mine density is high, with a design criterion of ensuring that 80-100 percent of all vehicles entering the field will be destroyed by mines.

"Turning" minefields are intended to persuade attackers to bypass the field in a specific direction rather than attempt to breach through it, thereby guiding the attacker into advantageous defensive terrain. They contain antitank mines only (without antihandling devices), in densities sufficient to destroy about 80 percent of vehicles entering the field.

"Disruption" minefields are intended to break up the attacker's formations, interfere with the timing and coordination of the attack, and force the attacker to improvise under fire. They typically cover only a portion of the likely approach route, and contain antitank mines only (with antihandling devices), in densities sufficient to destroy about 50 percent of vehicles entering the field.

"Fixing" minefields are intended to delay (but not halt) an attacker, typically in a prearranged engagement area against which the defender's weapons have been sited for maximum effect. Since the intent of a fixing field is to induce a breaching operation (with the associated delays), such minefields are not designed to appear impenetrable. Like disruption fields, they thus contain antitank mines only (but without antihandling devices), in densities sufficient to destroy about 50 percent of vehicles entering the field.

"Protective" minefields are laid by maneuver unit personnel (unlike the others described above, which are ordinarily emplaced by combat engineers) and are designed for close-in, last-ditch defense of deployed forces to prevent overrun in the final stages of an assault. They contain a mix of antitank and antipersonnel mines (without antihandling devices), in densities that vary significantly according to local unit frontages and mine availability.

In the deployment considered here, two turning minefields are used to canalize the attacker into a prepared engagement area near the center of the brigade frontage. A disruption field is used to disorganize the attacker's approach into the engagement area, and to encourage the attacker to narrow his assault frontage and break each attack echelon into a number of successive waves stacked one behind the other to be committed piecemeal as maneuver space becomes available. The engagement area itself is covered by a fixing minefield to slow the attacker's approach and maximize defensive weapon effectiveness. To create this engagement area, the strongpoint defense is disposed in the form of a roughly battalion-level kill sack shaped like a broad letter "U;" to protect the flanks of this formation

and to close a small gap between two of the individual company positions, three block minefields are deployed. The turning and fixing minefields are arranged in such a way as to provide a clear, high speed approach route for the reserve U.S. tank battalion TF to follow into the flank of the OPFOR attacker; the spatial arrangement of the minefields and the timing of the counterattack is intended to permit the tank battalion to strike the OPFOR just as it encounters the fixing minefield and begins to breach. Finally, protective minefields are arrayed to the immediate front of the company positions themselves.[22]

This is a very extensive mine deployment. To emplace such an elaborate barrier system would require a minimum of 85 engineer platoon-hours, in addition to the engineering effort required to prepare vehicle primary and alternate fighting positions for five companies of combat vehicles in the strongpoint defense. Many defenders will be unable to afford such an extensive effort.

The purpose of this formulation, however, is less to suggest an average or nominal mine deployment than to provide a bounding argument: a deployment this extensive should be highly likely to uncover any military advantages to be obtained from landmines. All primary tactical applications of mines (as described in U.S. Army *FM20-32: Mine/Countermine Operations*) are employed here in what represents a near "best case scenario" from the standpoint of landmine utility -- a very extensive, integrated minefield system which should exploit all the major capabilities of mines as described in the arms control debate to date.

Note, however, that in this base case the United States is engaged in both tactical defense (the mechanized battalion TF in the prepared strongpoint position) *and* tactical offense (the tank battalion TF assigned to counterattack into the OPFOR flank). This means that the OPFOR, as well as the U.S. forces, has the opportunity to employ landmines in support of its operations.

In particular, in this scenario the OPFOR artillery is allocated six battery volleys of scatterable antitank mines. These mines are employed by the OPFOR to protect the flank of its assault force as it closes with the U.S. strongpoint defense. In this first base case scenario, both sides thus engage in some local offense and some local defense, and both sides employ landmines to assist those friendly forces which fight on the defensive.

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22 The design of the defensive obstacle system given here and its integration into the brigade scheme of maneuver is drawn from the examples given in *FM20-32*, op. cit., pp.2-16, 2-20.

OPFOR units that encounter a turning minefield are assumed to elect to bypass rather than breach (as is the purpose of a turning field); OPFOR units that encounter a block minefield are assumed to withdraw and seek other approach routes rather than attempt to breach an apparently impenetrable obstacle. OPFOR or U.S. units that encounter any minefield within 200 meters of its edge, however, are assumed to observe the consequent opportunity for bypass and to maneuver around it. Otherwise, U.S. or OPFOR units that encounter minefields are assumed to attempt an immediate, in-stride breach.

This first base case is contrasted with seven excursions. The first of these eliminates all landmines on both sides. Of course, the dispositions of the U.S. defense in the base case are premised on the existence of an extensive mine system to restrict the OPFOR's freedom of maneuver and canalize the attack into a prepared engagement area. Without that minefield system, the original dispositions would have been extremely vulnerable to an OPFOR advance that would no longer be forced to proceed along the intended path, but would instead have easily struck the strongpoint forces in a now-exposed flank. As a result, the U.S. strongpoint defenses were redeployed in the first excursion into linear dispositions less sensitive to the particular direction of the attacking forces. Similarly, in the first base case the counterattack's axis of advance struck the OPFOR flank from an almost ninety degree angle -- because the counterattackers' own flank was protected by one of the two turning minefields, the approach to contact could be conducted in relative safety, and the point of counterattack could be directed against the OPFOR's most vulnerable location. In the first excursion, by contrast, this is no longer possible and the counterattack had to be directed along a much shallower angle.

The second excursion eliminated only antipersonnel landmines, leaving all antitank mines in place on both sides. Note that this affected only the U.S. (since the OPFOR was given only antitank mines in the first place). Note also that this affected only the U.S. blocking and protective minefields (a minority of the total) -- U.S. doctrine, as described in *FM20-32*, calls for *no* antipersonnel mines to be included in turning, disruption, and fixing minefields. Moreover, it should be noted that even in blocking and protective minefields, antipersonnel mines make up only a part of the total mines laid; even when AP mines are removed, a substantial obstacle thus remains, at least to vehicular traffic.[23]

23 Note that U.S. prepackaged scatterable mine systems contain a mix of AP and AT mines: the Volcano multiple delivery mine system, for example, uses prepackaged cannisters with a fixed ratio of 5 AT mines to 1 AP mine: this ratio cannot be altered in the field as a function of the tactical purpose of the

The third, fourth, and fifth excursions considered the effects of various potential substitutes for landmines. In the third excursion, the no-mines scenario described above was altered by adding larger quantities of U.S. artillery fire. More specifically, the number of M109 155mm howitzers available to the U.S. defender was varied between the base case total of 24 (three 8 gun batteries) and a maximum of 100. In the fourth excursion, artillery quality, as well as quantity, was increased by adding MLRS rather than M109s (with the numbers of MLRS launchers varying between the base case total of 8 and a maximum of 72). And in the fifth excursion, additional M2A2 Bradleys were provided to the U.S. defenders (with the numbers of BFVs varying between the 56 of the base case and a maximum of 136).[24]

The sixth and seventh excursions considered the effects of tactical offense on the utility of landmines. More specifically, in the sixth excursion the base case tank battalion counterattack was canceled, producing a purely defensive action fought from the prepared positions of the strongpoint defense. The extensive minefield system of the base case was retained, however, as were the specific dispositions of the U.S. mechanized battalion deployed within the strongpoint. In effect, excursion six thus represents the kind of purely defensive warfare implicitly assumed in much of the debate over the military utility of landmines. Correspondingly, excursion seven cancels the U.S. counterattack for the no-landmines defense described under excursion one above. Taken together, excursions six and seven thus provide a comparison of a pure defense conducted with an extensive landmine system and a pure defense conducted without landmines.

minefield: see *FM20-32*, op. cit., p.6-23. As the mines considered in base case I are hand emplaced, however, applicable doctrine was followed and AP mines were used only in block and protective minefields. Note, however, that the circumstances of the case are such that the OPFOR does not dismount infantry in the presence of other minefields even so -- note also that this is typically assumed in U.S. Army studies of scatterable mine effectiveness as well: telephone interview, Mr. Chuck Digney, U.S. Army Picatinny Arsenal, 13 June 1994. The results reported here are thus largely insensitive to the distinction between scatterable and hand emplaced U.S. mines.

24 Note that additional vehicles only were considered: no additional dismounted infantry were provided.

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## Experimental Design (cont'd.)

Base case II: U.S. mechanized battalion in defense, wooded terrain (South Korea)

- OPFOR regiment attack with dismounted infantry, tank/BMPs advancing on separate axes
- Block minefields used to canalize attack
- Fixing minefield used to hold attacker at optimum engagement range
- Protective minefield used for close-in defense

Excursions

a. No AP mines, no substitutes, U.S. or OPFOR

b. No AP mines, U.S. or OPFOR, additional U.S. direct fire systems as substitute

## SLIDE 3: EXPERIMENTAL DESIGN (continued)

The second of the two base cases is designed to shed additional light on the potential merits of antipersonnel mines in particular. While the previous slide presented an excursion in which only antipersonnel mines were eliminated and antitank mines retained, in some ways the first base case was not ideally suited for consideration of this particular excursion. In the kind of open desert warfare modeled there, attacking infantry would be relatively less likely to dismount from their vehicles and advance on foot (given the absence of cover for such an advance in the desert). And were they to do so, they would be very unlikely (if well trained) to attempt to advance without the covering fire provided by the heavy weapons on their supporting troop carriers and accompanying tanks, which would ordinarily be advancing in close proximity to the dismounted infantry. As a result, under such conditions AP mines per se rarely demonstrate much effect: foot soldiers are not often outside their vehicles in the attack, and when they [illegible], their advance rate is tied to that of their supporting vehicles. Either way, if antitank mines stop the vehicles, the foot soldiers are stopped as well -- with or without the presence of antipersonnel mines.

But while this is a useful insight, it is not clear that it provides full credit to the potential utility of antipersonnel mines. In particular, this observation is based on the relative infrequency of dismounted attack in the open desert, and the requirement that when infantry does dismount, it advances only in close proximity with its supporting vehicles. While this is generally the case for open terrain desert warfare, it is not necessarily the case for combat in other terrain types. In rough or heavily wooded terrain, for example, dismounted infantry and supporting armor are sometimes maneuvered on separate, converging axes (typically with the infantry advancing along a covered approach route through terrain impassable to vehicles -- for example, through a forest -- and the vehicles advancing and providing suppressive fire along a more open approach route into the same objective). Where this is the case, the presence or absence of AP mines alone might have a more significant effect on the outcome, independent of the presence of accompanying AT mines.

Base case II is designed to explore this possibility, and thereby to identify a situation more conducive to high effectiveness for antipersonnel mines -- if such a situation can be found. In particular, base case II considers a radically different terrain type: a rugged, heavily forested section of South Korea.

On this terrain, a U.S. mechanized battalion TF (plus one infantry company of an adjoining battalion with line of sight into the first battalion's sector) is deployed in a static defense position (no U.S. counterattack was considered here). This mechanized battalion TF is organized identically to that of its counterpart in base case I; it is further assumed to receive identical artillery support.

The OPFOR attack is conducted by a motorized rifle regiment, which, like the U.S. defender, is organized identically to that of its base case I counterpart; it likewise is assumed to receive identical artillery support. Unlike base case I, however, in base case II the component battalions of this regiment are assigned very different tasks. The first of these battalions, consisting of three companies of BMP2 equipped infantry, is transported via a concealed route to the edge of a heavily forested approach route which leads into the flank of the U.S. defensive position. There the infantry dismounts and begins its advance on foot. The remaining battalions detach a total of about three companies to provide suppressive fire from stationary overwatch positions, and conduct a mounted assault with the remainder up a relatively clear approach route to the right of the dismounted infantry attack. The two assault elements are timed to converge on the objective at about the same time.

The U.S. defenses are again supported by extensive minefields, but in such restrictive terrain, many of the maneuver-restriction minefields in base case I would be superfluous here and have therefore been discarded. Instead, two block minefields are used to preclude approach routes unsuited to effective defensive fire (thereby enhancing the natural canalization effects of the terrain itself). In addition, two fixing minefields are used to hold attackers at preferred engagement ranges longer along the remaining high speed approach routes, and a protective minefield is deployed for close-in defense of the prepared positions themselves. This protective minefield extends across the front of the OPFOR dismounted infantry advance, and provides the primary antipersonnel minefield to be encountered by the OPFOR in the course of the attack.

This second base case is contrasted with two excursions. In the first, antipersonnel mines are removed from the U.S. defense (with no U.S. counterattack, the OPFOR deploys no mines of its own in base case II or the associated excursions), but all other

characteristics of the second base case are held constant. Note that since none of the U.S. minefields were purely AP in either base case, the elimination of AP mines only here does not wholly undermine the rationale for the U.S. deployment here as it did before -- in the excursion, U.S. positions continue to be covered by minefields, those fields simply contain only AT mines.

In the final excursion, additional M2A2 Bradleys are added to the no-AP-mines scenario as mine substitutes (with the numbers of BFVs varying between the 42 of the base case and a maximum of 122).[25]

25 Again, additional vehicles only were considered; no additional dismounted infantry were provided.

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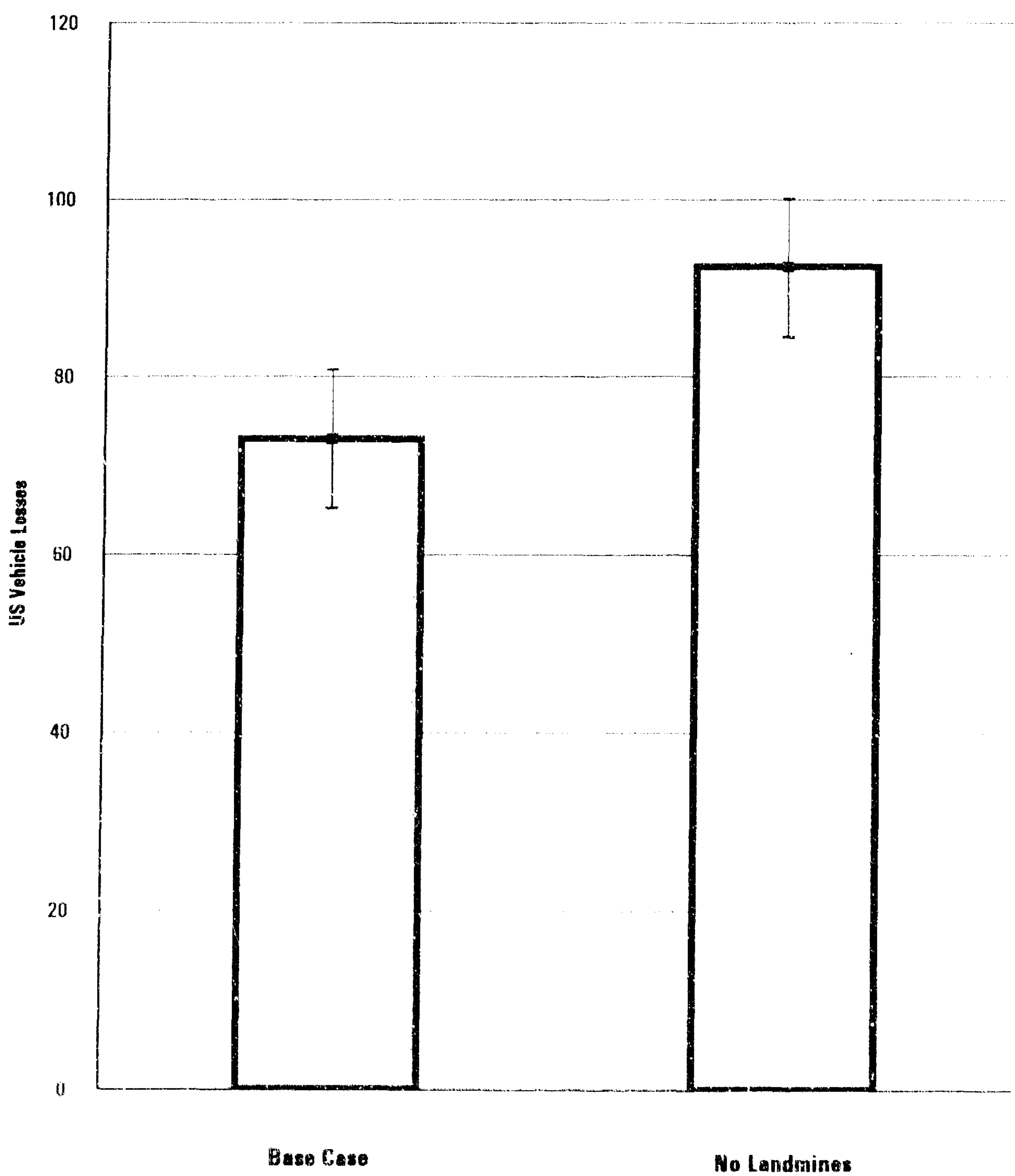
# SUMMARY OF RESULTS

## Case I Results: Military Utility of Landmines



## SLIDE 9: CASE I RESULTS -- MILITARY UTILITY OF LANDMINES

This slide presents the first of the analytical findings from the experimental design described in the last two slides. The slide plots mean U.S. vehicle losses for two scenarios: the first base case (U.S. mechanized brigade defense on desert terrain), and the no-landmine excursion. For each scenario, 95 percent confidence intervals are depicted in the form of brackets surrounding the mean outcomes; in each case, the results correspond to 15 separate iterations of the battle in question.

The results suggest that landmines do indeed have positive military utility for the scenario conditions considered. When provided the extensive mine deployment of the base case scenario, the U.S. brigade suffered mean vehicle losses of just under 75 (or about 47 percent of the U.S. total of 161). When those mines are removed, mean U.S. losses increase to about 92 (or 57 percent of the total). And the difference is very unlikely to be due to chance alone: the hypothesis that the difference between the two means is zero can be rejected at the .05 level of significance.[26]

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26 OPFOR vehicle losses averaged 136 in the base case and 137 in the no-mines excursion. (or about 83 and 84 percent of the first echelon OPFOR forces engaged in the initial assault), for loss exchange ratios (OPFOR losses/U.S. losses) of 1.83 and 1.48, respectively.

In almost all thirty runs, the military operational outcome was a successful, but costly U.S. defense, and an essentially annihilated OPFOR attack (typically, weakened by defensive fires from the strongpoint defense, then destroyed by the U.S. counterattack).

Note that a scenario yielding roughly this level of U.S. losses (i.e., around 50 percent) provides maximum leeway for the observation of military utility for landmines -- that is, it allows room for excursions to provide both meaningfully worse and meaningfully better outcomes as a function of the parameters being varied. By contrast, if the base case U.S. defense were substantially less effective (e.g., if U.S. losses approached 100 percent), then the removal of the U.S. minefield could not meaningfully increase U.S. losses, and the potential military effect of the minefield would be hidden. Alternatively, a substantially more effective base case defense might well be so capable as not to require mines for success at low casualty levels; in which case, again, the potential effect of the minefield would be indiscernible through the usual measures of losses incurred.

It is also interesting to note that very few of the OPFOR's base case vehicle losses were killed by mines (on average, about 0.93 vehicles, or less than one percent of the OPFOR's total vehicle casualties) -- and certainly far fewer than the seventeen losses separating the mean base case and no-mines excursion. In effect, it is thus the *indirect*, rather than the direct, attrition effects of the U.S. minefields that contribute the most to the outcome here. In the base case, the OPFOR is forced to adopt a highly disadvantageous plan of maneuver; the U.S. is able to adopt a highly advantageous disposition of its defenders; and the OPFOR is compelled to delay in positions of maximum vulnerability to the fire of those defenders. Though the OPFOR is able to avoid detonating many mines through a combination of bypass and breaching operations, mine warfare thus imposes serious costs anyway via a series of Hobson's

Yet the military utility observed here, while positive, is substantially smaller than typically asserted. In the arms control debate, it is often argued that the absence of mines would roughly double U.S. vehicle losses. In the results here, however, U.S. losses increase, but only by about 20 percent. Why is the difference so much smaller here?

The answer has to do with the effects of considering both tactical offense and tactical defense when assessing minefield effectiveness. In the base case, the OPFOR offensive suffers heavily as a result of the canalization and delay effects imposed by the American defensive minefields. But when the U.S. counterattack leaves its line of departure, it in turn encounters the scatterable minefields emplaced by the OPFOR's artillery to protect its flank. Now it is *U.S.* forces which suffer attrition and delay as a result of mine encounters.[27] In the no-mines excursion, the OPFOR assault is relieved of the difficulties associated with the U.S. minefield -- but the U.S. counterattack is also relieved of the difficulties imposed by the OPFOR minefield, which tends to counterbalance the effects of the change on U.S. losses.

Moreover, in the base case, the benefits of the U.S. mines accrue mostly to the tactically defensive battalion deployed in the strongpoint positions. Of course, the U.S. counterattack battalion also derives some advantage from the presence of those mines (e.g., they enable it to strike the OPFOR at a more vulnerable point, and they weaken and disorganize the OPFOR target); nevertheless, the counterattackers' fate is substantially less sensitive to the presence or absence of U.S. mines than is the fate of the static defenders in the

choices: charge through a live minefield and risk destruction from mine explosions, or take actions to avoid mine losses that create vulnerabilities to other defensive forces.

27 Note that if the roles were fully reversed -- e.g., a U.S. brigade attack against an OPFOR battalion defense where the OPFOR battalion deploys an extensive mine system and the U.S. brigade uses mines primarily to defend its flanks from counterattack -- then it is likely that the military utility results seen here would reverse as well (that is, that landmines would display a modest, but *negative* net military utility in such a scenario). For a more detailed discussion, see the more complete IDA analysis forthcoming.

strongpoint. As a result, the negative effects of removing the U.S. mines in the excursion case is felt much less strongly by the counterattack battalion. The presence of a counterattack force in the U.S. totals thus tends to damp the magnitude of the change in U.S. casualties as a whole when U.S. mines are removed, which again on balance tends to reduce the magnitude of the effect overall.[28]

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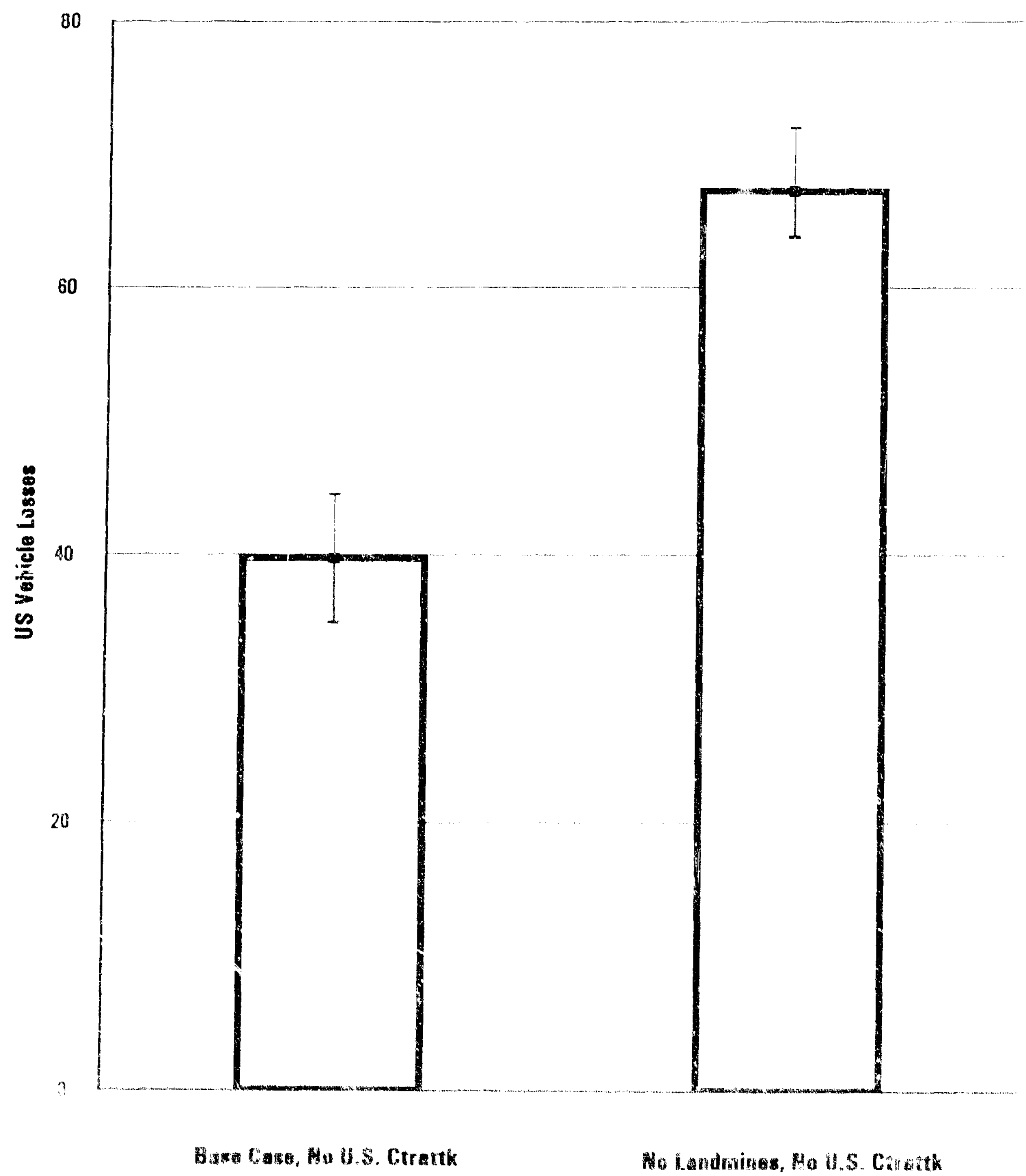
28 Of the roughly 73 U.S. vehicle losses in the base case, for example, about 43 were suffered by the counterattack battalion, and only 30 by the TF in the strongpoint defense behind the U.S. minefields. When the mines were removed in the excursion case, U.S. counterattack losses net out about the same (on the one hand, the counterattack benefits, as it no longer encounters OPFOR mines; on the other hand, the counterattack suffers by virtue of a less-advantageous direction of attack, and a stronger opponent in the absence of U.S. mines), but losses to the strongpoint defense TF increase to more than 40. If the counterattack battalion's losses were removed from the comparison, the result would thus be a much greater proportional increase in U.S. casualties.

## Case I Results: Static Defense



## SLIDE 10: CASE I RESULTS -- STATIC DEFENSE

To put the point in somewhat higher relief, this slide compares excursion scenarios 6 and 7 from slide 7 above. That is, it contrasts a version of the first base case in which the U.S. counterattack is canceled, but in which the base case mine system is intact -- with a version of the no-mines excursion in which the U.S. counterattack is likewise canceled but in which there are no mines on either side.

In effect, this slide thus considers only the purely defensive tactical warfare which is implicitly assumed in much of the arms control debate, and compares the results of conducting such a static defense with or without minefields.

Again the results depicted are the mean U.S. vehicle losses resulting from 15 repetitions each of the given scenarios; 95 percent confidence intervals for the means are depicted as brackets around the mean values.

Again the results suggest that landmines have positive military utility for the defender, but now the magnitude of the difference is much larger. Whereas in the previous slide, the absence of mines increased U.S. losses by only about 20 percent, here the absence of mines produces a roughly 70 percent increase.

The principal reason for this more stark result is the elimination of U.S. tactical offense from the analysis. Now only the OPFOR is affected by landmines; when all landmines are removed, the only side that benefits is the OPFOR. Moreover, the scope of the analysis here is effectively restricted to that part of the U.S. brigade as a whole whose fate is most sensitive to the presence or absence of U.S. mines -- i.e., the tactically defensive battalion in the strongpoint positions. Because the tactically offensive counterattack battalion is withheld from the battle, it is thus irrelevant to the outcome, which is consequently determined entirely by those forces whose effectiveness is the most heavily landmine-dependent. Overall, then, the result is a much greater predicted utility for landmines.

What, then, does this say about the relationship between the standard assessment in the arms control debate and the results presented in the previous slide? The answer is twofold.

What, then, does this say about the relationship between the standard assessment in the arms control debate and the results presented in the previous slide? The answer is twofold.

First, neither outcome is necessarily either correct or incorrect. The differences result from different assumed scenario conditions, one set in which the U.S. is assumed to operate on both the attack and the defense, and one in which it is assumed to operate on the tactical defense only. Neither assumption is inherently implausible.

Second, however, these two sets of assumptions are not equally general in applicability. The United States Army rarely fights a wholly-defensive campaign. It has seen few if any such campaigns in its history. And it could be argued that, if anything, the Army's orientation is likely to become *more*, not less, tactically and operationally offensive in the future, given its increasing post cold war emphasis on power-projection (as opposed to forward deployment).

Given this, it may be best to regard the purely defensive scenario considered in this slide as a special case for the more general issue of landmine utility -- where in the general case, the United States conducts both tactically defensive and tactically offensive combat activity, but where the special case of tactical defense *per se* remains an important, if partial, subset.[29]

29 Indeed, in the most general case, the United States would conduct not just brigade defenses with a mix of local (or tactical) offense and defense, but also brigade level *offensives* in which the effort is primarily, rather than secondarily, offensive in nature. For a more detailed treatment of this case, see the more complete IDA analysis forthcoming.

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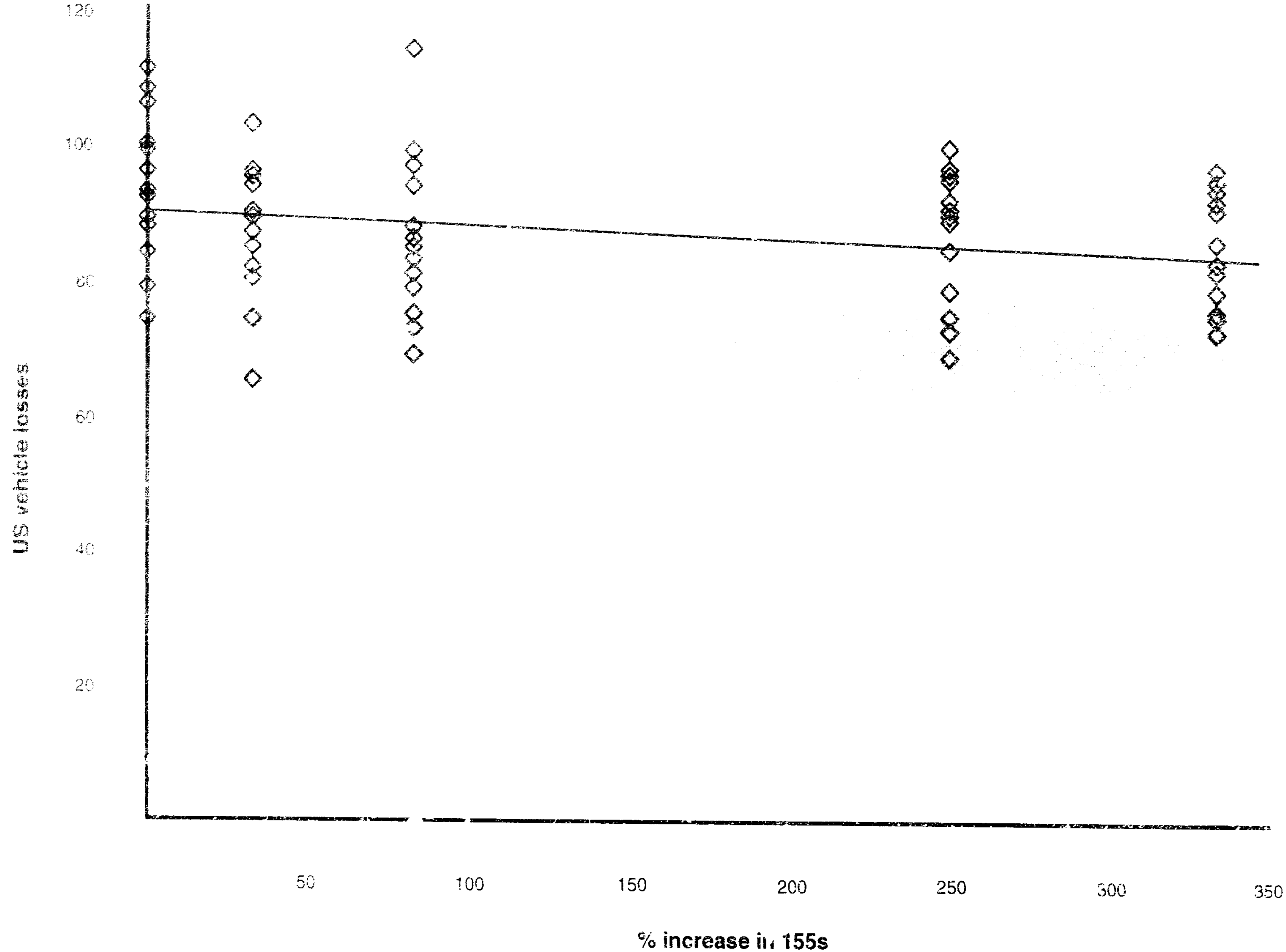
# Mine Substitutes: 155s in Case I



## SLIDE 11: CASE I RESULTS -- INCREASED 155mm ARTILLERY FIRE AS A SUBSTITUTE FOR LANDMINES

This slide is the first of three to consider the effects of substitutes for landmines. In particular, it evaluates the effectiveness of increased 155mm artillery fire as a potential substitute.

To do this, a series of Janus scenarios were constructed in which increasing numbers of M109 self propelled howitzers were added to the U.S. forces in the no-mines case described in slides seven and nine above. As the firepower available to the U.S. brigade increases, the outcome improves: that is, U.S. losses decline. The objective is to determine at roughly what level of increased 155mm firepower do U.S. losses in the absence of landmines decline to the level of U.S. losses in the base case defense with its extensive landmine deployment; that level of increased firepower could then be said to constitute an adequate substitute for the effects of the mines.

The results are illustrated by plotting U.S. vehicle losses against the number of additional M109 howitzers available to the U.S. brigade, expressed in percentage terms relative to the base case M109 total (thus a zero value indicates no additional M109s and corresponds to the original "no mines" excursion from slides seven and nine, while a value of 100 indicates twice the original number of M109s, 200 indicates three times as many, and so on). As Janus is a stochastic model, results vary from run to run. Fifteen replications were run for each increase in available M109s; each of these run results is plotted here as a separate data point, with a regression line fitted to the data and plotted to represent the central tendency of the results. For reference purposes, base case U.S. vehicle losses are given as a horizontal gray band delineating a 95 percent confidence interval around the base case mean. (Note that the conclusions reached are not sensitive to the specific point of intersection between the base case casualty results and the fitted regression line; the regression line is provided for illustrative purposes only, as an aid to the reader in visualizing the central tendency of the Janus output).

Of course, given the degree of variance inherent in the results for both the base case and the excursions, it would be unwise to identify a single intersection point as an "adequate" increase for substitution; the purpose of the slide is less to compute a specific intersection point per se than to suggest a region within which the associated increases are likely to provide comparable results on

average. It should also be noted that the substitution results shown here are best interpreted as an upper bound on likely U.S. losses for the given numbers of M109s: inasmuch as additional howitzers were employed in much the same manner as the existing ones, it is possible that other, better, employment opportunities may exist for the additional resources than those considered here. If so, then one could expect lower U.S. losses on average than those shown.

The results suggest that 155mm artillery is indeed an expensive substitute for landmines. Even a 300 percent increase in M109s (or about 72 additional guns) failed, on average, to reduce U.S. losses in the absence of mines to the mean level obtained with landmines. In fact, none of the increases considered here proved large enough to compensate fully with a high degree of confidence. These results are thus broadly consistent with the arms control debate's treatment of additional artillery as a substitute for mines: there is little here to suggest that 155mm artillery offers an adequate substitute.

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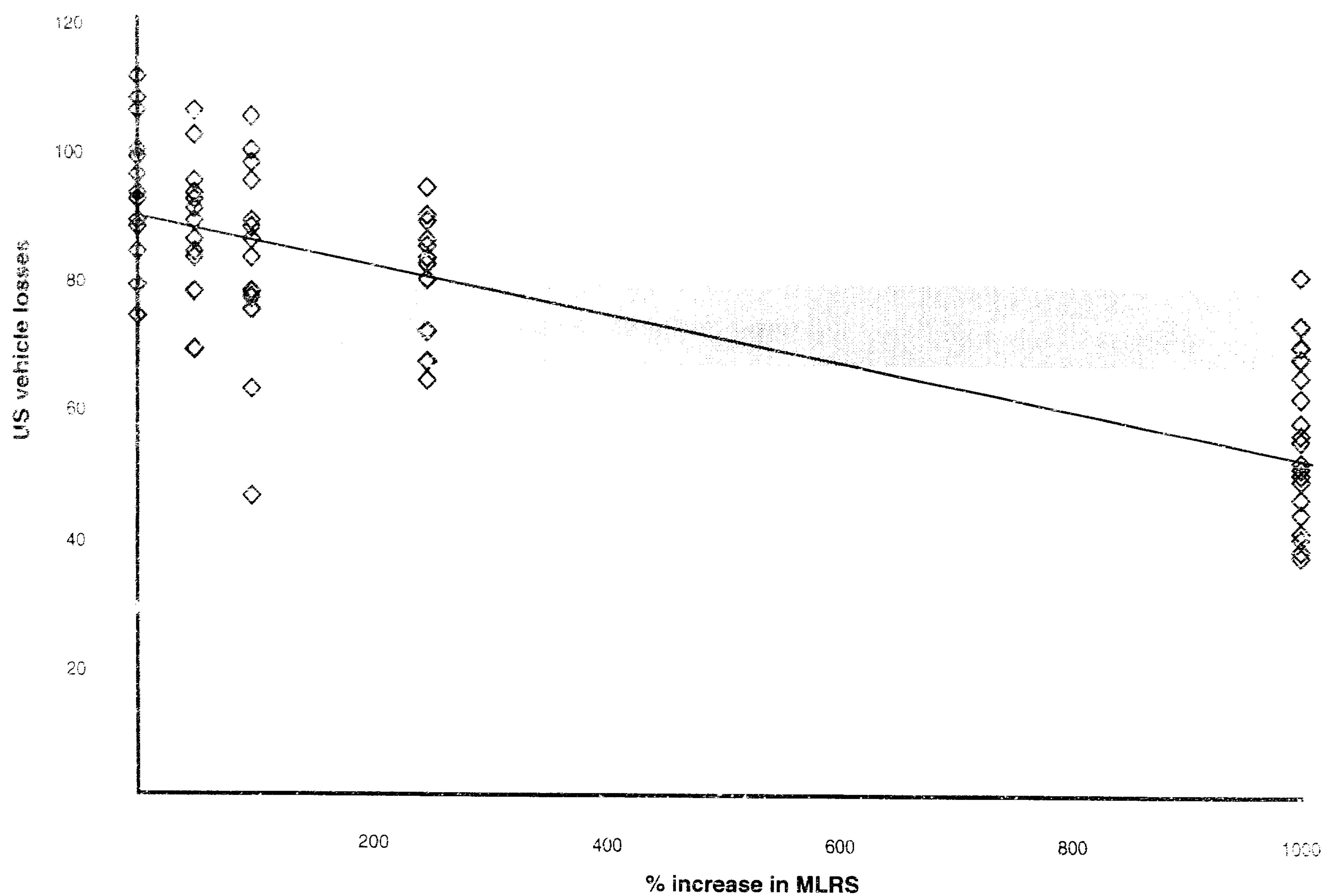
# Mine Substitutes: MLRS in Case I



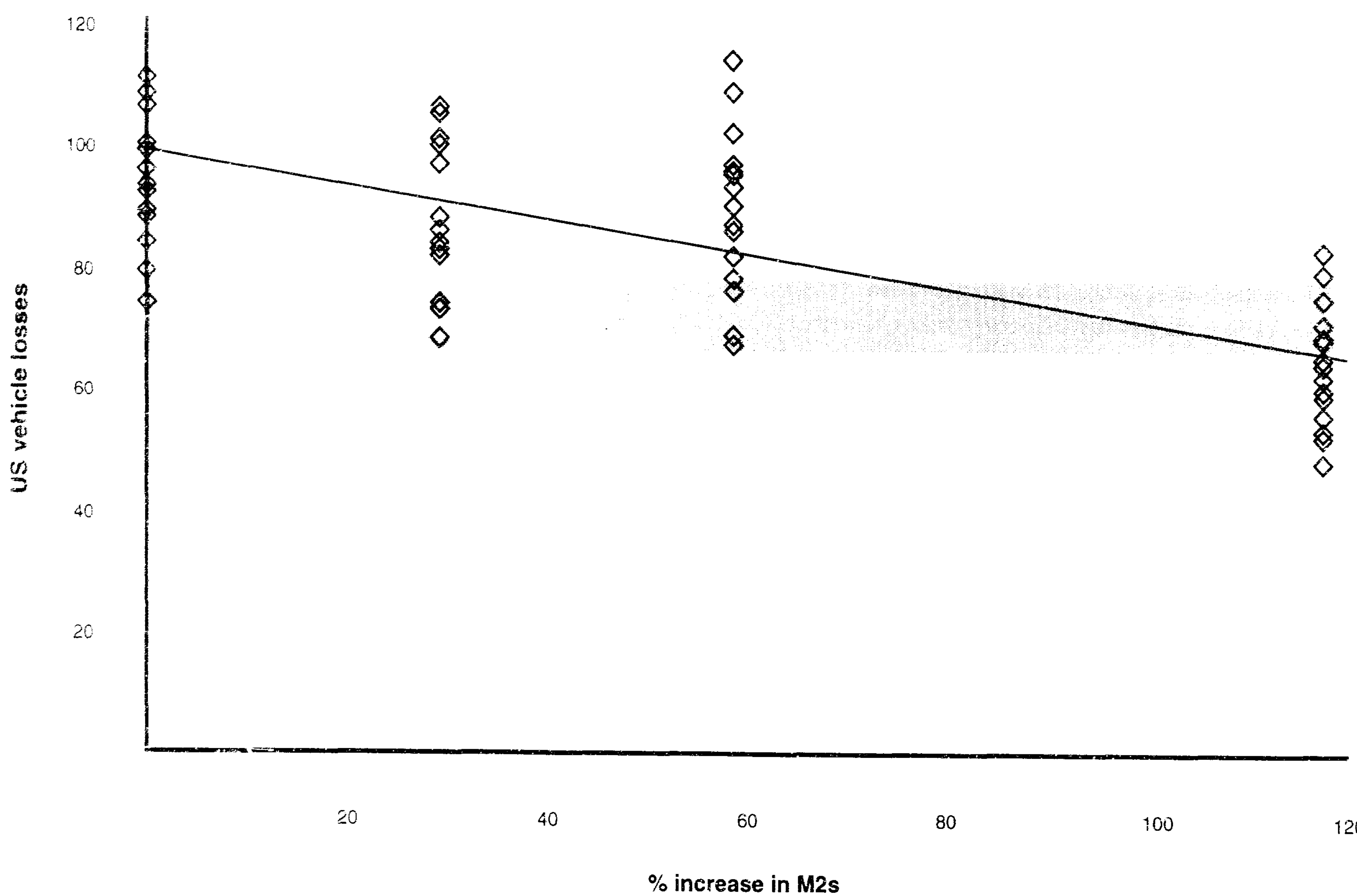
## SLIDE 12: CASE I RESULTS -- INCREASED MLRS AS A SUBSTITUTE FOR LANDMINES

This slide is the second of three to consider the effects of substitutes for landmines. In particular, it evaluates the effectiveness of increased numbers of MLRS launchers as a potential substitute.

The structure of the analysis and the format of the graph are much the same as those described in slide 11, except that, here, the potential mine substitutes took the form of additional MLRS launchers as opposed to M109 155mm howitzers. And of course, the limitations concerning the interpretation of specific intersection points described in the previous slide pertain here as well.

The results suggest that the substitution of more effective artillery support in the form of MLRS could well prove to be a more efficient substitute, though still an expensive one. The slope of the fitted regression line for MLRS is more than twice as steep as that for the M109s in the previous slide, and produces, on average, U.S. losses roughly equivalent to those of the base case mine deployment for an increase of between 200 and 700 percent in available MLRS launchers (or some 16 to 56 additional MLRS launchers, beyond the original 8). Of course, this is still a large increase in required fire support. While it is, again, best regarded as an upper bound on the required levels, it is certainly a high bound.

# Mine Substitutes: M2s in Case I



## SLIDE 13: CASE I RESULTS -- INCREASED M2A2 BRADLEYS AS A SUBSTITUTE FOR LANDMINES

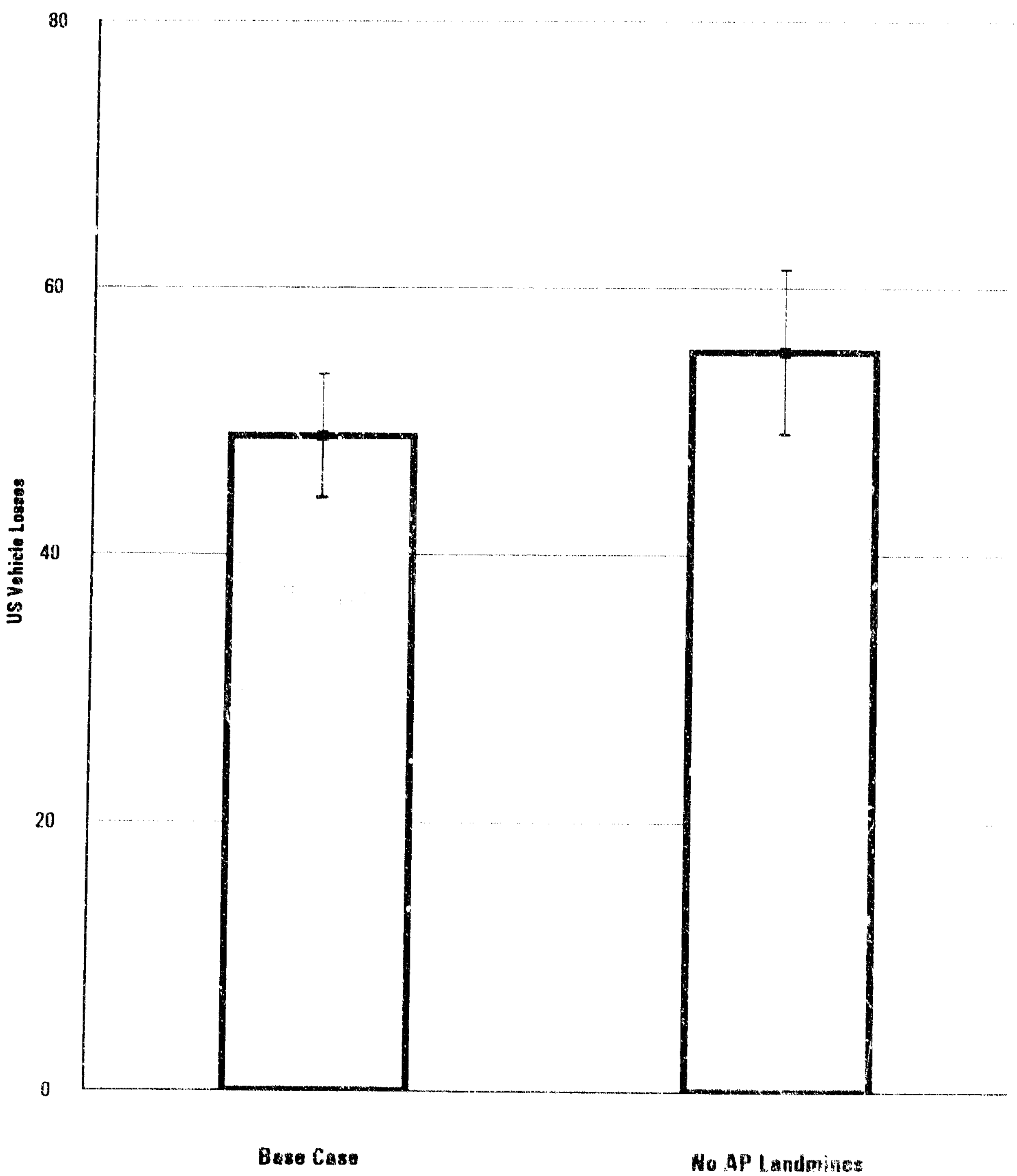
This slide is the third to consider the effects of substitutes for landmines. In particular, it evaluates the effectiveness of increased numbers of M2A2 Bradley Fighting Vehicles as a potential substitute.

Again, the structure of the analysis and the format of the graph are much the same as those described above, except that, here, the potential mine substitutes took the form of additional direct fire systems, and in particular, additional M2A2s. And once again, the limitations concerning the interpretation of specific intersection points described in the previous slide pertain here as well.

The results suggest that direct fire M2A2s are likely to be more efficient substitutes than 155mm artillery fire, and possibly more efficient substitutes than MLRS, although none of these appear to be inexpensive replacements. The slope of the fitted regression line for the M2A2 is more than six times as steep as that for the M109 howitzer, and produces, on average, U.S. losses roughly equivalent to those of the base case mine deployment for an increase of between about 40 and 200 percent in available M2A2s (or some 20 to 110 additional Bradleys, beyond the original 56). To determine whether this outcome represents a more cost-effective substitute than the MLRS would require a lifecycle costing effort beyond the scope of the current analysis, and in any case these results are meant only to be broadly suggestive rather than definitive in nature -- no direct answer to the question will thus be attempted here. But in any case it appears likely, at least for the scenario conditions considered here, to be a more cost-effective substitute than the M109 (for which even the largest increase considered, an additional 72 guns, did not approach the base case loss level).

Overall, then, these results suggest that at a minimum, there may well be more efficient substitutes for landmines than those suggested in the arms control debate to date. While the analyses conducted here are far from an exhaustive or exclusive evaluation, they have nevertheless identified at least two alternatives that appear in the scenarios considered here to be substantially superior to the more commonly discussed option of increased volumes of traditional artillery fire. None of the options considered here provide inexpensive remedies, however; the principal implication of these results should thus be to suggest that further exploration may be warranted before reaching a final conclusion with respect to the feasibility of any individual system as a substitute for landmines.

## Case II Results: Military Utility of AP Landmines



## SLIDE 14: CASE II RESULTS -- THE MILITARY UTILITY OF ANTIPERSONNEL LANDMINES

This slide brings us to the second of the two base cases described in the experimental design above, i.e., the U.S. mechanized infantry battalion defense on rough, forested terrain. The need for this case derives from some important properties of the first base case with respect to antipersonnel (AP) mines -- as well as some important properties of AP mines themselves.

In particular, none of the base case I trials produced an outcome in which the OPFOR tested any of the U.S. antipersonnel mines. This was for two reasons. First, only two of the six types of U.S. minefields contained AP mines: i.e., block and protective fields, and neither of these was extensively breached. The purpose of a block field is to thwart or preferably discourage breaching attempts; it was assumed here that the OPFOR would not attempt to breach such formidable obstacles under fire, and thus they were not engaged -- the OPFOR sensibly went elsewhere. Protective fields are located very close to the defenders' own positions (within small arms range); the high effectiveness of the remainder of the U.S. defensive mine system prevented most attackers from reaching the protective belt, and those that did were killed quickly, before they had a substantial opportunity to engage the mine barrier.

But second, and more important, even if the OPFOR had encountered more AP mines, the doctrinal requirement that infantry and supporting armor stay together would have meant that with or without AP mines, antitank mines alone would have been sufficient to halt the attack (as noted above). As a result, even if the U.S. AP mines had been removed; even if the OPFOR had reached the mine barriers that had previously contained AP mines; and even if they had dismounted their infantry upon doing so, there would still not have been any significant change in the outcome.[30]

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30 Note that since the OPFOR is assumed to breach minefields when encountered (not simply charge through them), it is unlikely that the OPFOR would have suffered significant infantry casualties from AP mines in any case. Just as the OPFOR loses very few vehicles directly to mines in the base case (the mines' effect is chiefly indirect), so the OPFOR would be very unlikely to suffer many personnel losses from mines. Their (indirect) effect would ordinarily be felt by delaying the relevant assault units and exposing them to other fire -- but since the infantry is effectively delayed even by AT mines (which delay their accompanying vehicles), the difference between AT and AP mines is thus moot here.

For AP mines to have a major effect on the outcome thus requires a number of important preconditions. First, the OPFOR attacker must be able to reach AP minefields in force. Second, the OPFOR attacker must be prepared to dismount his infantry from its carrier vehicles upon reaching this barrier (or before). And finally, and most importantly, the OPFOR must be willing to maneuver dismounted infantry and supporting armor separately -- otherwise, it is enough to stop the supporting vehicles with AT mines.

Note that these conditions are substantially more restrictive than those required for AT mines to be decisive. Under U.S. doctrine, AT minefields are deployed in a greater variety of potential battlefield locations. Moreover, almost all modern high intensity ground assaults involve armored vehicles, whether alone or in support of dismounted infantry. Far fewer modern assaults are conducted by dismounted infantry operating independently of armored support.[31] This in turn means that a wider range of potential attack types can be affected directly by AT mines than AP mines; and perhaps more important for arms control purposes, the set of attack types that *cannot* be affected directly by AT mines alone is relatively small (and thus, a mine inventory consisting solely of AT mines would still provide a substantially robust mine warfare capability).

This is not to say that there are no situations that meet these preconditions, however. The purpose of the second base case is to establish just such a set of circumstances, and thereby to evaluate the military utility of AP mines as distinct from AT systems in a scenario under which their unique effects could be discerned and measured.[32]

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31 Although, again, it should be emphasized that this conclusion is limited to high intensity mechanized land warfare -- as opposed, for example, to counterinsurgency or other low intensity conflicts.

32 This is not to argue that the scenario described here is the only one under which AP mines could have independent military utility; there are other circumstances that would also meet the preconditions described above. Examples might include night infiltration attacks; stealthy attempts (typically at night or in bad weather) by dismounted scouts to identify and remove AT mines prior to a mounted assault: or attempts to slip dismounted infantry between thinly manned outpost positions. It should be noted, however, that a wide range of non-landmine responses to counter-infiltration and night/bad weather surveillance are becoming available. While a full analysis of the capabilities of unmanned monitoring and surveillance systems is beyond the scope of this document, it should nevertheless at least be noted that several such systems are under intensive development, especially for use in situations (such as peacekeeping) where U.S. forces are unlikely to be permitted to use landmines.

Alternatively, there are terrain types (such as jungle or mountains) where vehicular movement is largely impossible and most combat will be conducted dismounted. Under such conditions, AP mines will in general be more significant than they are, for example, in the desert. On the other hand, our focus here is on more or less traditional mechanized high intensity conflicts, rather than the kind of guerrilla or counterinsurgency warfare more typical of such

As discussed above, base case II involves a combined mounted-dismounted attack on separate, converging axes. The dismounted attack is conducted along a covered, forested approach route impassable to vehicular traffic but leading into a position near the flank of the U.S. battalion defense; the mounted attack is directed along a reasonably open approach route with a line of departure some two to four kilometers to the right of the infantry's (concealed) dismount point, but with an objective point coincident with that of the infantry

The terrain in this scenario thus creates an opportunity for an attacker to benefit from separating dismounted infantry from its supporting vehicles. The forest offers a concealed approach route to a tactically advantageous position, but one which is closed to armored vehicles and can only be exploited by dismounted infantry. Moreover, the nearest trafficable avenue for mounted advance is initially several kilometers away, thus increasing the odds that the two assault elements will proceed independently (rather than one halting in the event of a setback to the other).[33]

This slide contrasts this second base case scenario with an excursion in which AP mines only are removed, but an extensive U.S. AT mine deployment is left in place. For each scenario 15 repetitions were run; the values reported represent mean U.S. vehicle losses, with 95 percent confidence intervals on those means depicted as brackets around the mean values.

The results suggest that, for the scenario conditions described here, AP mines do have military utility -- but the magnitude of that utility is quite modest. U.S. losses in the "No AP mines" excursion are higher than in the base case benchmark, but by only about 10

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environments. For a more detailed treatment of landmine utility in low intensity conflicts, see the more (forthcoming) documentation of the more extensive IDA analysis now ongoing.

Finally, it should also be noted that in conflicts with some developing states the U.S. could also encounter Iranian-style "human wave" attacks conducted by largely unsupported dismounted infantry. But given the United States' enormous firepower advantages in such fighting, it is difficult to envision circumstances under which AP mines would be required to halt such attacks. While helpful, they would thus probably not be decisive in themselves.

33 As is still possible, and indeed would still be militarily advisable, anyway, but which would again tend to dilute the military utility of AP mines per se, since an AT mine-induced setback to the mounted element would then still be sufficient to halt the attack.

percent (or about 55 vehicle losses in the excursion, vice 49 in the base).[34] And in fact, the null hypothesis that the observed difference is due entirely to chance can only be rejected at the .10 level of significance.

The primary reason for the modest nature of the difference is that the OPFOR dismounted attack suffers considerable losses when it reaches the U.S. position, even if there are no AP mines in front of that position. All U.S. defenders preplan what is known as a "final protective fire" (FPF) line immediately in front of their positions to help deal with close-in penetrations by hostile forces. Protective minefields are sited in such a way as to tie in with FPF lines, but even if there are no AP mines, there is still an FPF. Final protective fires include all weapons at the defender's disposal, but especially, any friendly artillery. Dismounted infantry is extremely vulnerable to hostile artillery fire, especially if caught outside foxholes or other protective positions during an assault. In the base case, this vulnerability is accentuated by the OPFOR infantry's encounter with the U.S. protective minefield; the OPFOR infantry attempts to breach this field and continue the assault, but the breaching delay exposes them to the U.S. FPF fire too long, and the result is that they are typically wiped out before they can close with the U.S. defenders themselves. In the excursion case, there is no U.S. AP minefield to breach, but even without this, U.S. final protective fire takes a heavy toll of the exposed OPFOR foot soldiers as they close with the defense. In the excursion, enough OPFOR personnel often survive to enable them to overrun those U.S. positions closest to the initial point of contact, but that infantry is so depleted by the effort that they can rarely continue much further. The net result is a small increase in mean U.S. losses in the excursion (as a consequence of the OPFOR's ability, on average, to overrun some U.S. positions if able to advance without breaching an AP minefield) but the difference is not large.

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34 Or about 60 percent of the U.S. total of 81 in the base case, and 68 percent in the excursion. Mean OPFOR vehicle losses came to about 95 in the base case and 100 in the excursion (or about 59 and 62 percent, respectively, of their total of 161), for loss exchange ratios (OPFOR losses/U.S. losses) of about 1.9 and 1.8, respectively.

Note that although AP mines kill infantry, the primary purpose of the infantry action in this scenario is to kill (or preserve) major weapons systems -- i.e., combat vehicles. AP mine effectiveness is thus measured in terms of its ultimate effect on vehicle kills (which is a function of the AP mines' ability to kill infantrymen who would otherwise kill vehicles), rather than by counting infantry losses per se.

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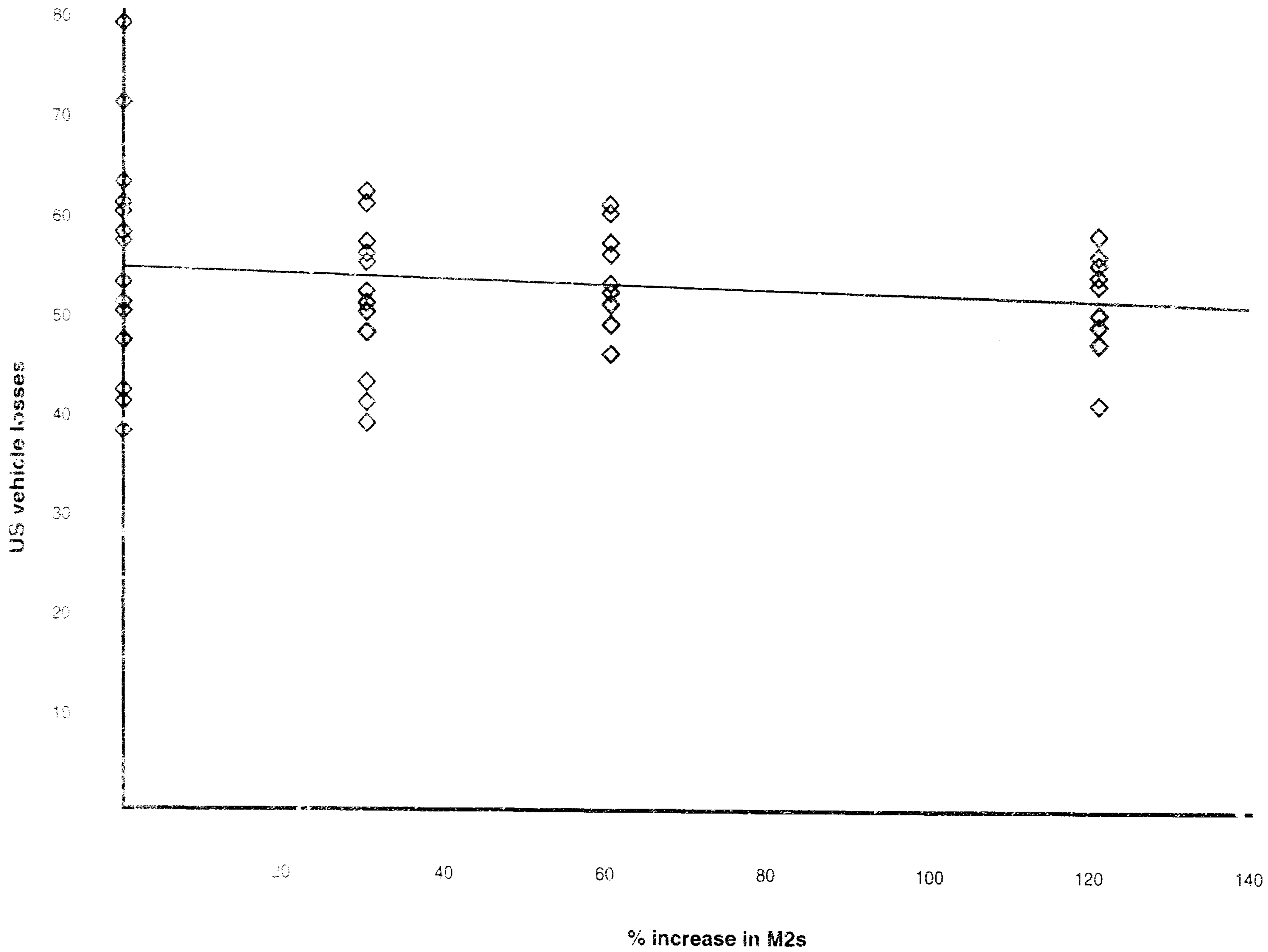
# Mine substitutes: M2s in Case II



## SLIDE 15: CASE II RESULTS -- M2A2 BRADLEYS AS SUBSTITUTES FOR ANTIPERSONNEL LANDMINES

Although the effect was modest, mean U.S. losses did increase when AP mines were removed from the second base case scenario. What would be required to substitute for the effect of the mines?

To address this question, a substitution analysis was performed in essentially the same manner as those described in slides 10 through 13. For this analysis, however, a narrower range of potential substitutes was considered -- and in particular, we looked primarily at the M2A2 Bradley as a more or less representative direct fire alternative.

This slide presents the results of that analysis. The structure of the analysis and the format of the graph are much the same as those described in the earlier slides. And once again, the limitations concerning the interpretation of specific intersection points described in the previous slide pertain here as well.

The results suggest that the Bradley is in some ways a less efficient substitute in the rough, forested terrain of the second base case than in the open desert of the first. The largest substitution tested (about a 120 percent increase over the base case M2 force) failed to compensate completely for the absence of AP mines; a projection based on the available results implies that somewhere between a 150 and a 350 percent increase might be necessary to restore the performance of the base case defense. In desert terrain, the TOW missile of the Bradley is often able to engage targets at ranges in excess of 4 km. At such distances, the thin skin of the lightly armored Bradley is little tested by return fire. In the close terrain -- and consequent short lines of sight -- considered here, however, the long potential weapon range of the Bradley cannot be exploited. As a result, the impact on the combat outcome of additional Bradleys is more modest, and the number of systems required for complete substitution is correspondingly higher. Again, however, this result is best viewed as an upper bound on likely substitution requirements. Not only could the Bradleys themselves be used in different, and possibly more effective, ways than those considered here, but it is also likely that other potential substitutes will perform more effectively in the given terrain type.

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# CONCLUSIONS AND IMPLICATIONS

## Conclusions and Implications

Landmines have military utility in high intensity conflict, *but:*

- Magnitude of utility depends strongly on assumptions about balance of U.S. offense and defense
  - -- Mines mostly benefit defenders
  - -- If U.S. assumed to fight largely on offense, utility modest
- Utility varies strongly by mine type
  - -- AP mines require special conditions for significant impact
  - -- AP mine impact may be substantially smaller than AT mine impact even when these conditions obtain
- Asymmetric alternatives may be more efficient than symmetric to compensate for loss of landmines
  - -- Completely offsetting substitution may be expensive, however

Conclusion: military utility in high intensity conflict need not preclude consideration of landmine arms control

-- AP mines may warrant first consideration

## SLIDE 16: CONCLUSIONS AND IMPLICATIONS

What, then, do these results imply for landmine arms control? The analyses described above support three principal summary observations. First, landmines do have military utility in high intensity mechanized land warfare. They can have a significant effect on battlefield outcomes by canalizing attacks, providing economy of force, increasing attacker losses, and decreasing defender losses, as has been widely suggested in the debate.

But second, the magnitude (and even the direction) of that effect is strongly related to the nature of the fighting assumed, and the types of landmines considered. In particular, landmine use primarily benefits tactical defenders.[35] U.S. forces, however, are unlikely to fight exclusively defensive (or exclusively offensive) military operations in the future. On the contrary, some mix will surely characterize most future U.S. uses of force. The more the balance in this mix tends toward the offensive, however, the smaller the net military utility of landmine warfare to the U.S when both we and our opponents employ landmines. Indeed, the analyses conducted here provide little reason to believe that two-sided mine use would not yield a *negative* net military utility to the U.S. for scenarios involving straightforward U.S. attacks (as opposed to the primarily defensive actions considered here). In any event, however, it is clear that the assumed balance of offense and defense has a major impact on the net military utility of landmines -- and the results here suggest that it is only when the U.S. fights mostly or entirely defensive actions that this utility approaches the magnitudes usually cited in the public debate (e.g., arguments that the absence of landmines could double U.S. losses).

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35 Possible exceptions include the use of scatterable mines to defend an attacker's flanks (as considered in base case I, above); the use of scatterable mines to interfere with the withdrawal of a tactical defender; and the use of air or long range missile delivered mines to interdict the movement of a defender's reserves in the deep rear. For a more detailed consideration of the second of these exceptions, see the more complete IDA analysis forthcoming. As for the third, while a complete analysis of this possibility is beyond the scope of the current or ongoing effort, the problem has been the subject of other, prior analytical efforts: see, e.g., Stephen Biddle, D. Sean Barnett and David G. Gray, *Stabilizing and Destabilizing Conventional Weapons* (Alexandria, VA: Institute for Defense Analyses, 1991). IDA P-2548, pp.A-10 to A-13. These analyses suggest some net benefit for theater-level attackers from the use of such systems under at least some conditions, although they can also be used advantageously by theater defenders in slowing the attacker's commitment of follow-on forces, and especially, in interfering with the attacker's commitment of exploitation forces in the event of offensive success forward. We do not believe that such uses significantly alter the conclusion given above.

With respect to landmine type, the results here suggest that antipersonnel (AP) mines are of substantially more restricted utility than antitank (AT) mines. For AP mines to have a decisive effect, a number of important preconditions must be met, among these being: (1) that the attacker reach the close-in positions where U.S. doctrine places most AP mines; (2) that the attacker's infantry dismounts and conducts the assault on foot; and (3) that the attacker maneuvers this dismounted infantry and its accompanying armored vehicles independently.

Of course, there are battlefield situations which meet these conditions (e.g., the scenario modeled as base case II above); this is not to argue that AP mines are without military utility. Rather, it is to argue that: (a) the conditions under which AP mines have significant utility are considerably more restrictive than for AT mines; and (b) the magnitude of that utility, when it does obtain, may be smaller, given the inherent vulnerability of dismounted infantry to a wider range of other, non-landmine, weapons on the modern battlefield.

The third principal summary observation is that the potential substitutes for landmines cited most often in the debate may not be the most efficient possibilities available. In particular, the options most often cited are what might be termed "symmetric" substitutes such as increased artillery fire or non-explosive obstacles, whose immediate effects most closely resemble those of landmines. On the other hand, the results here suggest that "asymmetric" substitutes like increased numbers of direct fire systems (such as M2A2 Bradleys or M1 tanks), or improved artillery fire effectiveness (e.g. through increased use of MLRS, as opposed to 155mm howitzers), might compensate for the effects of landmines at lower cost, even though their effects do not immediately resemble those of a minefield.

It should be noted, however, that none of the analyses conducted here suggest that complete substitution for the contribution of landmines on the tactical defense will be inexpensive. Although the results given above constitute likely upper bounds on the substitution requirements for a given level of landmine utility, nevertheless the bounds identified are high. Further investigation would be warranted to explore the possibilities for more efficient substitutes than those considered here, or for more efficient use of the weapon types that were considered.

Overall, then, these results suggest that concerns for lost military utility in high intensity conflict need not necessarily preclude consideration of any form of landmine arms control. A rather demanding set of assumptions and preconditions are required for the

military utility of landmines in such conflicts to be so high as to make arms control unworthy of further consideration. And in particular, for the utility of *antipersonnel* mines to be so high as to preclude further consideration requires an especially demanding set of assumptions about the nature of future warfare. It is far from obvious that the required assumptions can be sustained.

Of course, this is not to say that any particular proposal is or is not in the U.S. national interest. To determine this requires consideration of a wider range of issues than military utility alone.

And perhaps more important still, such a conclusion ultimately requires a value judgment to weigh the dissimilar quantities associated with landmine arms control -- the most an analysis such as this one can do is to sketch the magnitude of the military consequences of certain classes of agreement; to weigh those military costs against the humanitarian benefits associated with landmine limitations is a task beyond the scope of any analysis such as this one.

Thus there are clearly many issues to consider beyond those addressed here before an informed conclusion can be reached on any particular proposal. Nevertheless, on the basis of the results obtained here, we believe that it would be a mistake to foreclose further consideration of those issues on grounds of military utility alone.

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**LIMITATIONS**

# Limitations

- Analysis limited solely to military utility
  - Other issues must be considered to determine whether arms control is in net U.S. interest
- Janus experiments designed narrowly to test specific assumptions underlying military utility debate
  - Results do not constitute general, scenario-independent statements of landmine effectiveness
- Analysis limited to high-intensity, mechanized land warfare
  - Low intensity conflict, initial entry operations, operations other than war must be considered to provide complete picture of military utility
- Janus -- like any model -- is imperfect representation of reality
  - Results must be interpreted with care

## SLIDE 17: LIMITATIONS

Like any analysis, the assessment that produced these conclusions is subject to some important limitations. While we do not believe they significantly weaken those conclusions, these limitations should nevertheless be kept in mind when considering their application.

First, as noted above, the analyses presented here are limited solely to the evaluation of the military utility of landmines. Clearly, other issues must be considered to determine whether landmine arms control in general, or any individual proposal in particular, is in the net interest of the United States.

Second, the Janus experiments on which our analytical conclusions chiefly rest were designed narrowly to test a discrete set of specific assumptions underlying the arms control debate to date over issues of the military utility of landmines. These experiments were not meant to provide general, scenario-independent statements of landmine effectiveness, and should be used outside the analytical context established here only with great caution.

Third, the analyses conducted here considered only high intensity, mechanized land warfare. Landmine use in other conflict types such as low intensity conflict, initial entry operations involving light forces, and operations other than war must be considered to provide a complete picture of the military utility of landmines in general.

Finally, Janus, like any model, is necessarily an imperfect representation of reality. While we believe the verisimilitude and flexibility of Janus are appropriate to the analytical questions addressed here, the results of any model-based assessment should always be interpreted with a certain degree of care.

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This briefing evaluates the military utility of landmines in high intensity, mechanized land warfare and draws implications from this for landmine arms control. While military utility is clearly only one of wide range of issues bearing on the advisability of any particular arms control proposal, it has nevertheless played an unusually important role in the debate to date. While IDA is continuing a broader assessment of this issue, it is hoped that this more narrowly focused analysis will shed some important, if necessarily partial, light on that broader debate.

The basic conclusion of the briefing is that issues of military utility in high intensity conflict need not preclude further consideration of landmine arms control. A rather demanding set of assumptions and preconditions is required for the military utility of landmines in such conflicts to be so high as to make arms control unworthy of further consideration. And in particular, for the utility of *antipersonnel* mines to be so high as to preclude further consideration requires an especially demanding set of assumptions about the nature of future warfare. It is far from obvious that the required assumptions can be sustained.

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